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LEARNING IN THE NEONATE: THE MODIFICATION OF BEHAVIOR UNDER THREE FEEDING SCHEDULES

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THE PROBLEM

There is lack of agreement among psychologists concerning the learning capacity of the newborn human infant. Several investigators (**9**, **12**, **20**) have presented evidence showing that it is not impossible to establish conditioned responses during the neonatal period. Most of this evidence suggests that such responses are unstable, variable, and difficult to establish. Other investigators (**10**) deny that conditioning can take place before the third or fourth month, because of the immaturity of cortical function in the newborn. A recent study (**21**) has proposed that a process of 'sensitization' rather than true conditioning occurs during this early period. In spite of this lack of agreement, few observers of a newborn baby, I believe, would deny that behavior *is* modified by environmental stimuli during the first weeks of life. The human infant is born into a time-regulated world. From the moment of his birth he must begin to adapt to schedules set up not on the basis of his precise physiological needs but regulated as well by parental activities and by other cultural demands calculated to be *on the average* best suited to his survival. He is granted only a few years leeway to adapt himself completely to the twenty-four-hour diurnal rhythm of activity which in our culture has been adopted as the basis of social participation.

An attempt was made in this study not to study behavioral modification in a conditioned response situation, which must of necessity be subject to 'artificial' laboratory control, but to observe signs of behavioral adaptation in a situation common to most newborn infants: the feeding schedule imposed in the pediatrics ward of a modern hospital. *Specifically, do infants adapt to* [*i.e.*, *'learn'*] *a feeding*

schedule within the first ten days of life? An investigation of this question, it was felt, would throw some light on the earliest stages of the socialization of the human individual.

The studies of Irwin, Richards, and others (**5, 6, 7, 16, 17**) have suggested that bodily activity in newborns increases in a curve of positive acceleration during the three- to four-hour period between feedings. Richards (**17**) has concluded that neither blood-sugar levels nor gastric contractions are simple determinants of this increment of bodily activity. Carlson (**2**), Taylor (**19**), and others, moreover, have shown that the average time of appearance of stomach contractions in the neonate after feeding is 2.3 to 2.7 hours—a period of time which does not necessarily correlate with pronounced increase in bodily activity (**5, 6, 7**). *Is 'learning,' therefore, an additive factor in determining the course of activity between feedings?* To determine this, the following studies were made:

1. Measurement of the general bodily activity of a group of newborns on a four-hour schedule during the period of their hospitalization. Daily changes in crying, activity, etc., might serve as evidence of 'learning' or adaptation to the schedule.
2. Measurement of the general bodily activity of a group of newborns who were on a three-hour schedule for a period of eight days and who were changed to a four-hour schedule on the ninth day. A comparison of the activity pattern of this group with that of the group which had been on a four-hour schedule for the whole period of hospitalization was designed as an experimental test of whether the former had 'learned' the three-hour schedule and would show an activity pattern different from that which would have occurred if they had been on a four-hour schedule from the beginning. Since a sufficient time for learning the three-hour schedule was important, it was not thought advisable to make the test [*i.e.*, change to a four-hour schedule] until the ninth day. This was unfortunate in that the stability of the adaptive behavior could not be tested by continued observation over a period of more than a day. (An experiment is in progress, however, to study this problem.)
3. Measurement of the bodily activity of newborns on a 'self-schedule,' who were fed when 'hungry.' Although the three-hour schedule more nearly than the four-hour approximates the natural rhythm of gastric motility, as described by Carlson, etc. (**2, 19**), it nevertheless does not exactly coincide with this rhythmicity. The 'self-schedule' group was designed to serve as an indication of what the natural feeding rhythm might be under the conditions of our experimental set-up.

Subjects, Apparatus, and Procedure

Subjects.—The aim was to set up an experimental situation in which, with a minimum of laboratory control, the behavioral studies described above could be made. Subjects were newborn infants of the Pediatrics ward of the New Haven Hospital.[1] The infants were selected by the following criteria: normal birth, good physiological condition as determined by examination after birth, birthweight 2900–4100 grams. Although infants who were to be breast-fed were given preference, prediction of successful breast feeding over the ten-day period was so precarious that it was not made an absolute criterion of selection. If at any time during the ten-day period an infant showed symptoms of physiological upset (diarrhea, fever, etc.) he was returned to the regular hospital nursery and his experimental record discarded. Thirty-eight infants, observed from Day II through Day IX of their hospitalization, were included in the experimental group. Record of activity was begun on Day II rather than Day I for two reasons: first, two days in the regular hospital nursery furnished greater insurance of discovery of physiological abnormalities; second, since no food was ingested during the first two days, inclusion in the experimental period was not deemed necessary. The infants were divided into experimental groups as follows: 18 on a four-hour schedule, 16 on a three-hour schedule, 4 on a self-schedule.

Apparatus.[2]—Two regulation nursery bassinets, equipped to measure general activity, were set up in a quiet room in the New Haven Hospital. Since the object of the experiment was to study adaptation in a relatively 'naturalistic' setting, a quiet rather than a sound-proof room was chosen. The room was kept in a dim light at a temperature of 80°–85°F. Each bassinet in its frame was supported at the foot end by a one-inch steel bar which acted as a fulcrum. The head end was suspended by a half-inch coil spring from an upright wooden bar. By means of a pulley and string the movements of the bed were transmitted to the pen of a polygraph and recorded on a wax-paper tape which moved at an approximate rate of one inch per half-minute. A magnetic time marker marked time units of half-minutes. The apparatus was calibrated so that slight movements such as breathing or muscular twitchings were not registered, but so that the shift in position of the head or arm of an infant of the size included in our experiment was recorded. Crying, hiccoughs, regurgitation, and any other unusual forms of activity were recorded on the tape by the nurse or experimenter in charge.

Procedure.—For the *three- and four-hour-schedule* groups, the procedure was as follows. Two infants on the same feeding schedule were studied simultaneously. They were placed in the experimental beds, with light covering, after the 6:00 A.M. feeding on the second day after birth. A registered nurse was on full-time duty, and either she or the experimenter was present at all times in the experimental room. With the exception of removal for feedings, the infants remained in the cribs throughout the day until the 6:00 P.M. feeding. Although record was taken of activity throughout the 12 hour period, the record from the 6:00 A.M. until the next feeding was not used in computation of results for two reasons: (1) the infants were bathed immediately after the 6:00 A.M. feeding before being placed in the cribs, so that the period was shortened; (2) the period after the 6:00 A.M. feeding was employed as a period of 'acclimation' to the experimental room after the night spent in the hospital nursery. At feeding times the activity record was discontinued, diapers changed, and the infants removed from the cribs.

Feeding.—Because of the possible importance of amount of food in determining activity, special precautions were taken to insure an adequate food intake. Infants were weighed before and after each feeding. In the case of breastfed infants, the nurse or experimenter remained in the room with the mother and infant during the feeding. All the routine pediatric procedures were employed to insure the maximum food intake. These included comfortable position for mother and baby, rest periods for baby, picking up of infant at least twice for air expulsion, keeping baby awake, etc. Nipple shields were used only when prescribed by the obstetrician in charge of the mother. The time allowed for feeding was made variable, to take account of individual differences in infants and mothers.[3] The infant was permitted to nurse

[1] The writer wishes to express appreciation to Dr. Grover F. Powers and to the nursing staff of the Department of Pediatrics for making available the facilities necessary for carrying out this experiment.

[2] The writer is indebted to Dr. Walter R. Miles for assistance in the design of the apparatus.

[3] In the early stages of the experiment, eight infants were allowed to nurse for twenty minutes at breast according to hospital routine, and then were routinely offered supplementary feeding from the bottle. As it was discovered that the infants began to take less from the breast and more from the bottle, the procedure was changed to permit unlimited time at breast.

as long as he sucked or could be induced to suck, or until the milk supply was exhausted. If his increase in weight after feeding indicated that he had not ingested an amount containing the number of calories prescribed by the pediatrician as optimum for his age and weight, supplementary formula was offered and the infant was permitted to feed from the bottle until he was 'satiated' [*i.e.*, until he could be induced to suck no longer]. In all cases an attempt was made to regulate the minimum amount but not the upper limit of food intake. In some cases infants continued to suck and whimper after the breast had been emptied even though weight change had shown that they had obtained a sufficient amount of milk according to hospital standards. In these cases also, a supplementary formula was offered. The criteria of satiation were admittedly subjective. The routine procedure after the infant had ceased sucking was to pat him for air expulsion, attempt to awaken him, and to offer breast or bottle again. If no sucking response occurred, the infant was judged satiated. Only one infant consistently became 'satiated' before he had ingested an amount standard for his age and weight. Bottle fed infants were fed by their own mothers when possible. They were offered at each feeding 30 cc. to 60 cc. more formula than the amount prescribed for their age and weight, and were permitted to such until satiated according to the above criteria.[4]

After feeding, the infants were returned to the experimental room, diapers were changed, and the activity record continued. The time out of bed for feeding averaged approximately forty-five minutes. Three-hour infants were fed at 9:00, 12:00, 3:00 and 6:00 o'clock, four-hour infants at 10:00, 2:00, and 6:00 o'clock. Thus there were three daily activity periods recorded for the three-hour group, two for the four-hour. The three-hour group spent in the experimental beds approximately thirty minutes per day less than the four-hour. After the 6:00 P.M. feeding the infants were returned to the regular hospital nursery where they remained for the night. Night feedings were carried out on a strictly regulated schedule (every three or four hours) the same as day, except that the regular hospital nurses were unable, because of time limitations, to remain constantly with the mother. The mother was instructed however to carry out the night feedings the same as during the day as far as possible. Weights were systematically taken before and after feeding.

Since the infants usually left the hospital on the morning of Day X, the activity records were discontinued at the end of Day IX. When the three-hour group was changed to a four-hour schedule on Day IX, feeding times were 9:00 A.M., 1:00 P.M., and 5:00 P.M.

For the '*self-schedule' group*, feeding procedures were the same except for times of feeding. The times for feeding were determined in the following manner. An infant could be fed after one hour had elapsed since the beginning of the last feeding. An arbitrary limit of one hour was set because of the exhaustibility of the mother's milk supply, because there was occasional crying immediately after feeding because of digestive disturbances, and because experimental evidence (**19**) has shown that gastric hunger contractions do not appear sooner than sixty minutes after feeding in the newborn. If after an hour an infant cried for five minutes, he was picked up, patted for expulsion of air, changed, and replaced in his crib. If crying continued for one minute he was fed. The 'self-schedule' infants were on 24-hour observation in the experimental beds because of the individual attention necessary for each infant.

The above experimental set-up furnished, it was felt, a fairly natural setting for the study of early feeding habits. Since the conditions for the three experimental groups were similar, a comparison of results could be made in the absence of such controls as soundproofing, absolute light and temperature control, etc.

Results

Activity was measured in terms of the percent of half-minutes active per unit of time. A half-minute was counted active if any activity occurred within it. This is essentially the method employed by Garvey (**4**), Johnson (**8**), Marquis (**13**), and Renshaw, Miller, and Marquis (**15**). The obtained results cannot be compared directly

[4] That the above feeding procedures were satisfactory was shown by the fact that the subjects in the experiment took more food and gained more weight than a control group of infants under standard hospital routine.

with those of Irwin (**5, 6, 7**) and of Pratt, Nelson, and Sun (**14**), whose technique of oscillations per minute of the stabilimeter pen gave a somewhat different measure of activity. Percents were used, since the periods between feedings were approximate rather than identical in length.

Daily Changes in Pattern of Activity during Days II–IX

Figures I and II show the daily distribution of activity for the three- and four-hour groups, plotted for successive ten-minute intervals in the periods between feedings for Days II–IX inclusive. Each daily curve [5] for the four-hour group represents the average for two between-feeding periods per day (10:00–2:00, and 2:00–6:00), and for the three-hour group the average of three between-feeding periods per day (9:00–12:00, 12:00–3:00, 3:00–6:00).

Four-hour.—Figure I shows that, on the average, throughout the eight-day period, the four-hour infants took some time to 'settle down' on being put to bed after feeding. They reached their period of greatest quiet sometime between ¾ and 1½ hours after being put to bed and then showed more or less increase in activity until the next feeding time. Although, as shown in Fig. IV, total activity per day was only slightly less on the last three days than on the first three days, the distribution of activity within the period changed somewhat. Activity during the first and last half-hours of the period remained respectively approximately equal throughout the eight-day period. The difference in the total activity on the last three days was due chiefly to decrease in the activity in the period between the first and last half-hours (29 percent vs. 34 percent). A lower level of activity was reached sooner after feeding during the last three days, and the increase in activity before feeding was more abrupt and was shifted nearer to the next feeding time during the last three days. In summary, during the eight-day period, the four-hour infants tended to remain just as active immediately after feeding but to settle down more quickly and to a quieter sleep. This period of quiet sleep lasted longer toward the end of the eight-day period, and the increase of activity after this 'sleep' tended to come more abruptly in relation to the next feeding time.

[5] Because the main experimental interest lies in the later portions of the period [*i.e.*, in activity *before* feeding], all curves of distribution of activity are plotted from averages computed after superimposing the termini of each period. The time when the infants were taken out for feeding was constant. Since there was, however, a variation averaging five to fifteen minutes in the time they remained out for feeding, the alignment of averages for the activity curves was made from the end rather than the beginning of the period. In order to avoid spurious values at the beginning of the curve due to a small number of cases determining the first one or two points, the first point represents the time at which more than half the group was included.

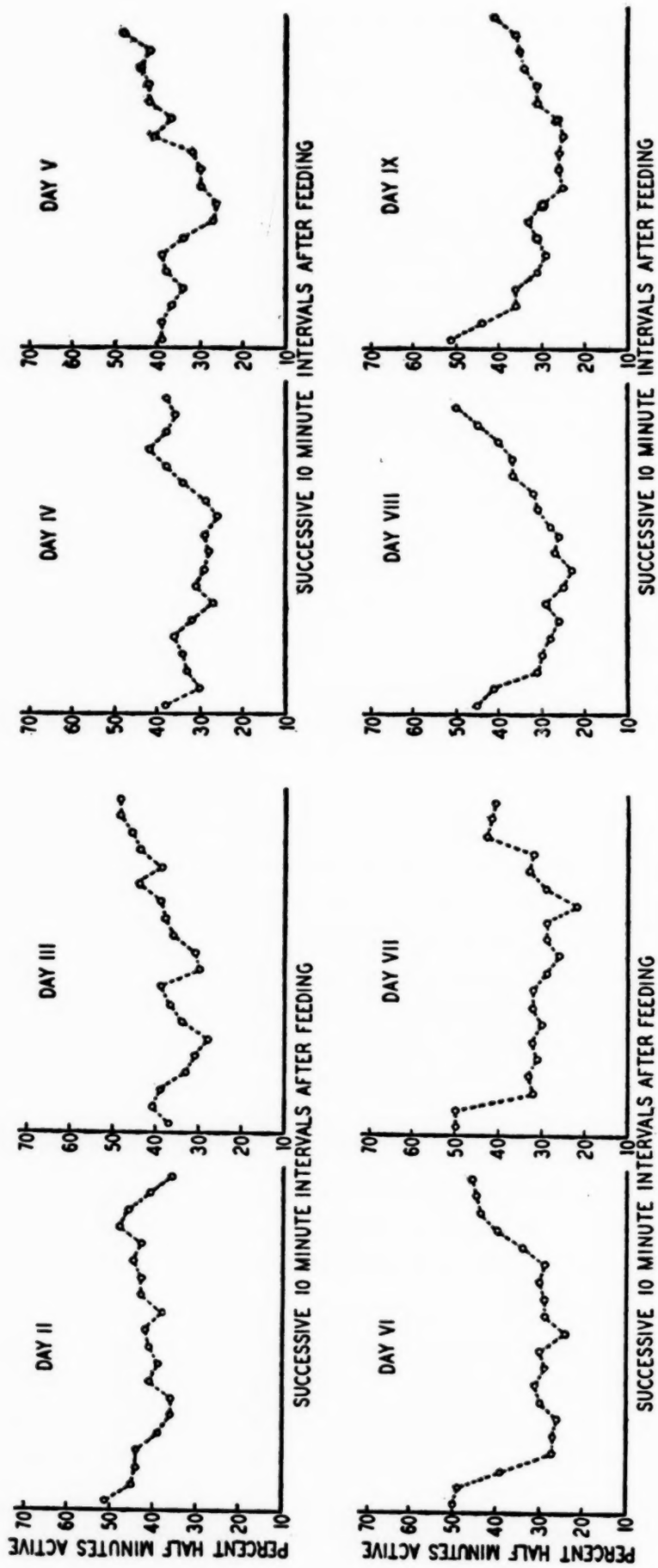

FIG. I. Four-hour group. Percent half-minutes active in successive ten-minute intervals during the interfeeding period. Average of all subjects.

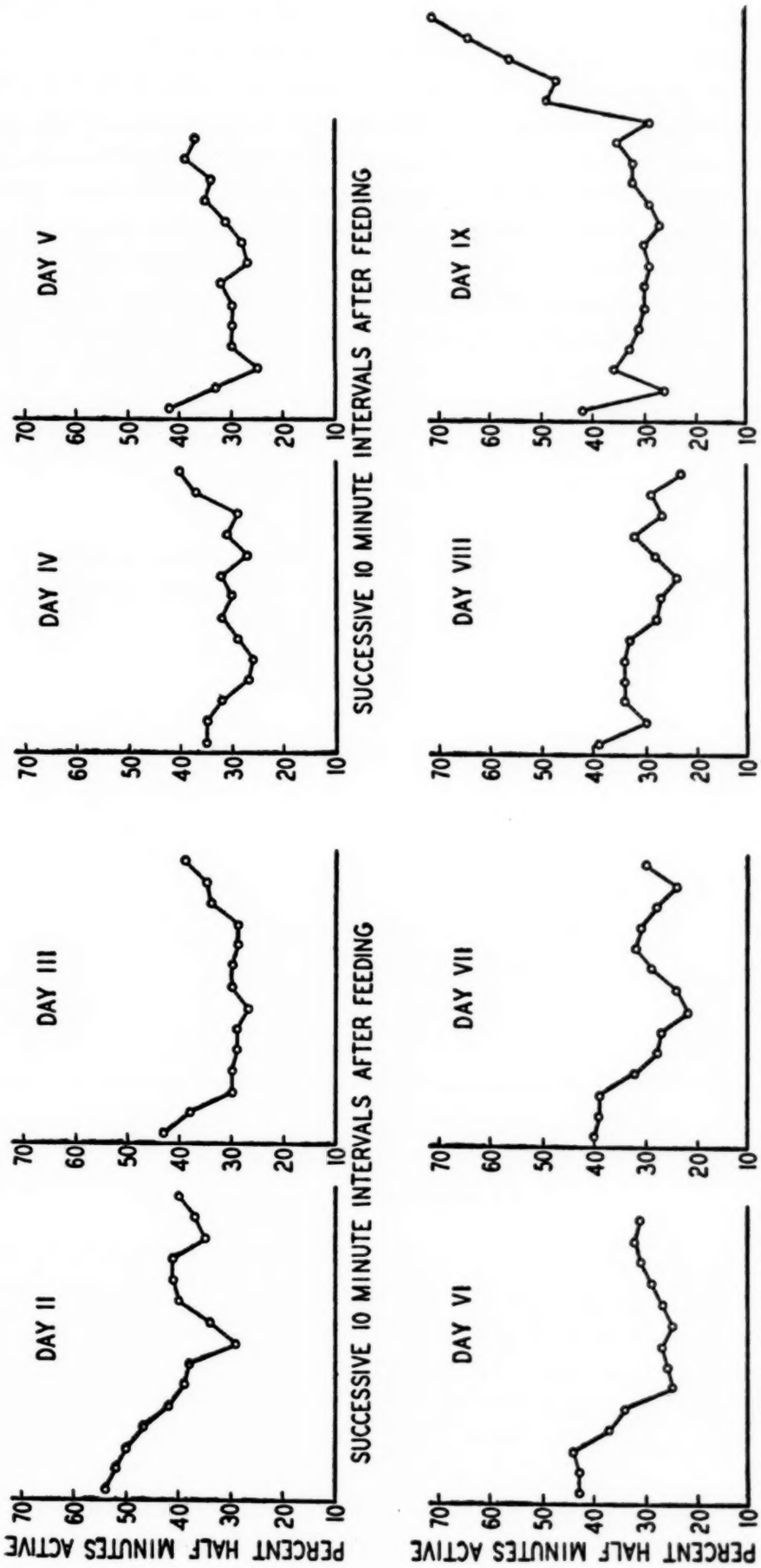

FIG. 11. Three-hour group. Percent half-minute active in successive ten-minute intervals during the interfeeding period. Average of all subjects.

Three-hour.—Figure II shows the activity pattern of the three-hour group over the eight-day period. For Days II–VIII [*i.e.*, before the group was placed on a four-hour schedule], the activity pattern differed somewhat from that shown by the four-hour group: (1) the three-hour group was not so active immediately after feeding; (2) the three-hour infants were slightly quieter on the whole than the four-hour, this difference being more apparent on the first days; (3) there is not the abrupt rise in activity before the next feeding, but rather a growing tendency toward less activity before feeding.

The most apparent day-to-day change in activity pattern was the progressive decrease in activity level during the second and third hours. Since this modification was similar for both three- and four-hour groups it probably represents a growing physiological stability rather than a change due to feeding schedule.

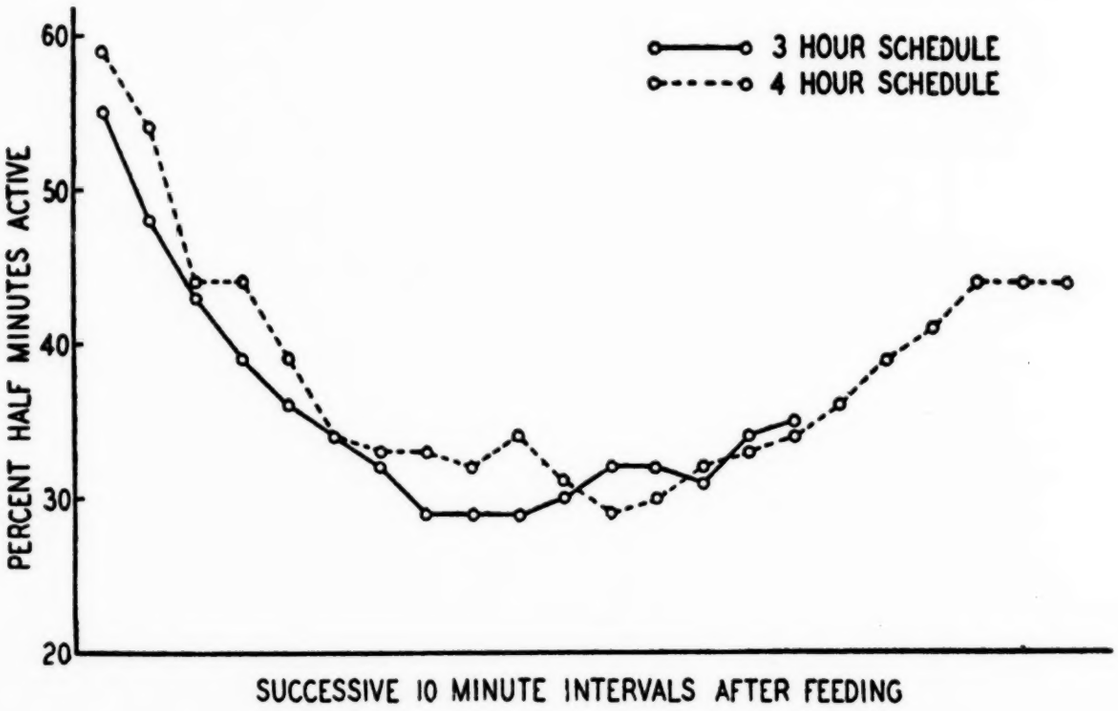

FIG. III. Comparison of three- and four-hour groups in interfeeding activity pattern. Average of all subjects, days II–VIII.

Figure III compares the average distribution of activity for the three- and four-hour groups during the eight-day period. The similarity of the curves is more striking than their dissimilarity. After the first 100 minutes the curves are so similar that the three-hour curve looks like the four-hour curve arbitrarily cut off an hour early. From this it might have been predicted that when the three-hour infants were changed to a four-hour schedule, their activity curve, other things being equal, would approximate that shown by the infants who had been on a four-hour schedule from the beginning.

Change in Activity Pattern When Three-hour Group was Shifted to Four-hour Schedule on Day IX

What did happen when the infants who had been regularly fed at three-hour intervals were suddenly on Day IX shifted to a four-hour schedule? Figure II shows graphically the striking change in activity pattern. At the point where the infants had usually been fed, activity increased abruptly until, during the half-hour before the next feeding, it reached a level which was not only higher than it had been at any time during the eight-day period but also higher than that shown by the four-hour group at any time. Figure II*a*, in which

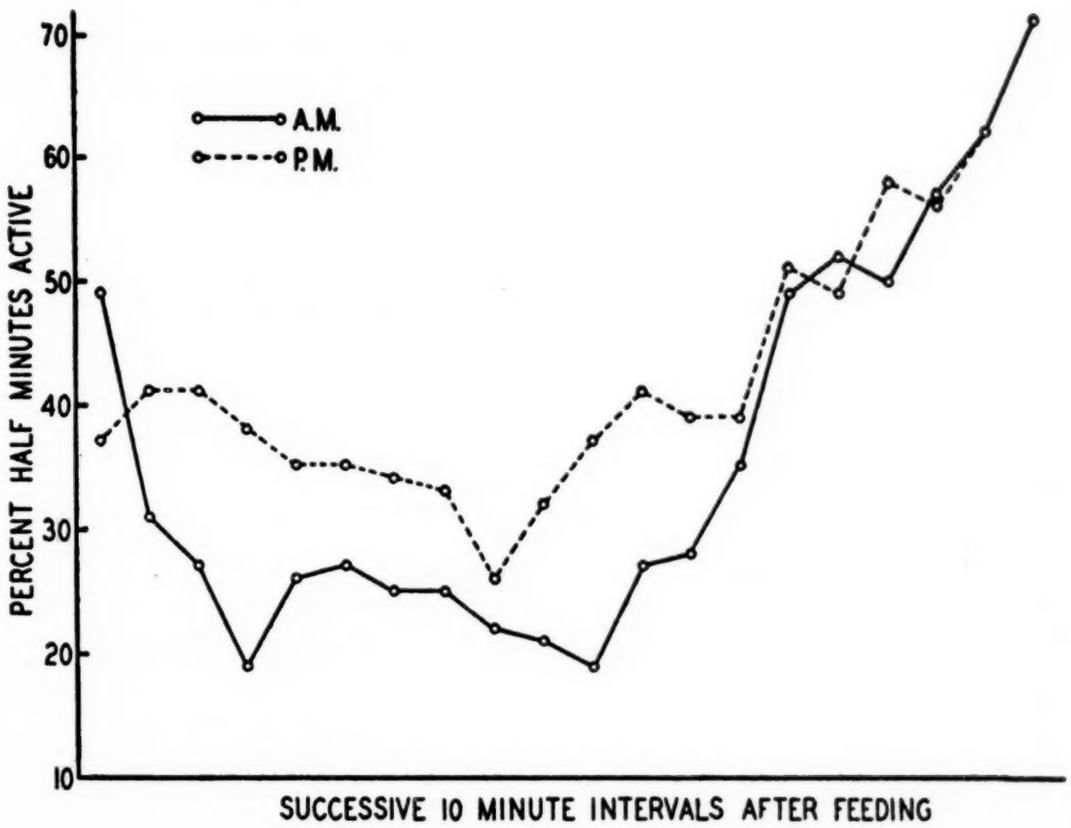

FIG. II (*a*). Three-hour group. Percent half-minute active in successive ten-minute periods of the morning and afternoon interfeeding intervals on Day IX, when change to a four-hour schedule was made.

morning and afternoon periods are plotted separately, shows in detail the changes which occurred. The infants, having been put to bed as usual after their last three-hour feeding (9:00 A.M., Day IX), quieted after a ten-minute interval of activity to a level of activity which was lower than that shown on any day previously. They remained quiet up to the time when they had been accustomed to be fed. At that time, food not being given, activity rose abruptly and continued at a high level, frequently accompanied by crying until food was given at the end of four hours. After this feeding (at 1:00 P.M.) they were

again returned to bed and activity for the second 'four-hour' (actually 200 minutes) period recorded. It might have been expected that the infants would have been so fatigued from the excess activity during the hour before feeding that they would sleep sooner and more quietly after feeding. The opposite however was the case. Activity was higher than usual throughout the period, but again showed an abrupt rise at the end of the three-hour period similar to that shown in the morning during the first four-hour period.

Comparison of Three- and Four-hour (Control) Groups in Total Activity on Days II–VIII and in Activity on Day IX

Figures IV and V and Table I summarize the activity differences in the three- and four-hour groups for Days II–VIII and on Day IX.

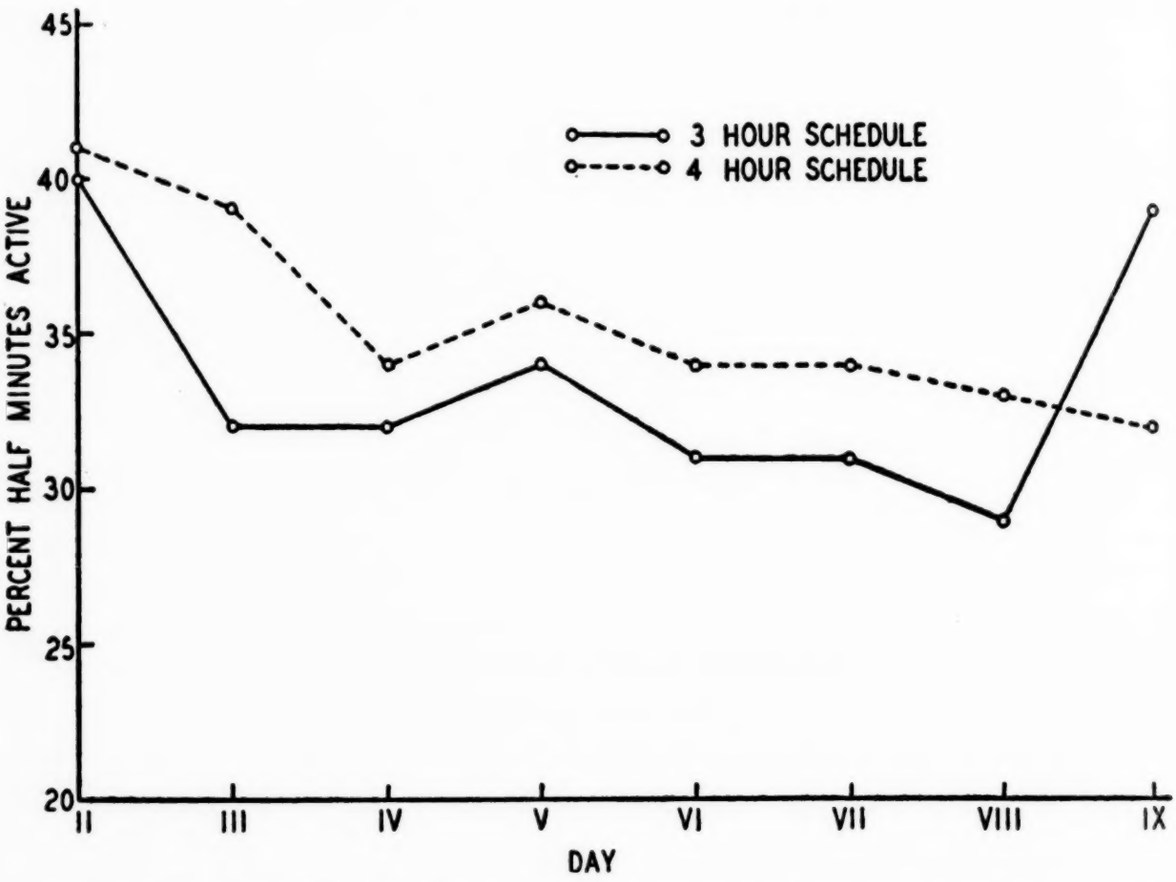

FIG. IV. Comparison of three- and four-hour groups in total amount of activity per day. Average of all subjects.

These figures indicate that the four-hour group was slightly more active than the three-hour on Days II–VIII. This difference was apparent on every day, although it does not meet the criterion of statistical reliability. On Day IX the direction of the difference was reversed, the three-hour group showing 7.5 percent greater

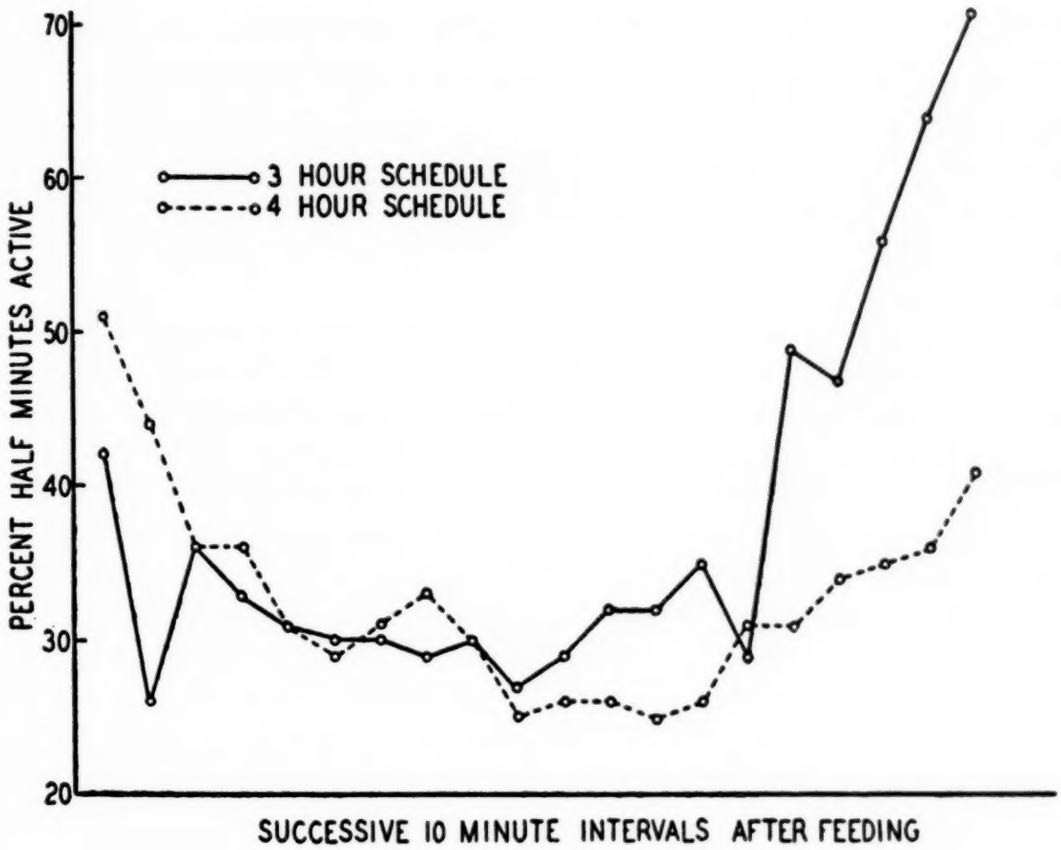

FIG. V. Comparison of three- and four-hour groups on Day IX, when three-hour group changed to a four-hour schedule. Average of morning and afternoon periods for all subjects.

TABLE I

PERCENT OF ACTIVE HALF-MINUTES PER HOUR. AVERAGE OF ALL SUBJECTS

		3-Hour	4-Hour	Difference	σ Diff.	Crit. Ratio
Days II–VIII.....		32.8	35.7	+2.9	2.43	1.2
Day IX	Total for day....	39.4	31.9	−7.5	2.96	2.5
	Last hour.....	53.0	35.0	−18.0	1.0	3.9

activity than the four-hour for the whole day. For the last hour the difference was + 18 percent (C.R. = 3.9) for the three-hour group.

That this increase in activity shown by the three-hour group is not a chance difference is shown in Table II by a comparison of the activity of the group on Days VI, VII, and VIII with that on Day IX.

TABLE II

COMPARISON OF THREE-HOUR GROUP ACTIVITY ON DAYS VI, VII, AND VIII WITH THAT ON DAY IX

Percent half-minutes active	Days VI, VII, VIII	30.5
Percent half-minutes active	Day IX	39.4
	Difference	8.9
	σ difference	2.2
	Critical ratio	4.1

Effect of Other Variables on Activity

The question immediately arises: Is this abrupt increase in the activity of the three-hour group at the time when they had usually been fed a sign of 'learning' and adaptation to a feeding schedule, or can it be explained in some more obvious way? An attempt was made to check various factors other than schedule which might have been contributory.

1. *Food Intake and Activity.*—The first question which might arise in a discussion of contributory factors is this: Was the food intake of the three-hour group, which had formerly received eight feedings per day, sufficiently less at the first four-hour feeding period than that of the four-hour group, which had only six feedings per day, to produce a physiological state of hunger and resultant activity at the end of three rather than four hours? The evidence points to the contrary. Although the four-hour group took slightly more food than the three-hour at the two feedings preceding the four-hour intervals on Day IX, the difference was not sufficient to account for the difference in activity. Table III gives a comparison of the food intake of the three- and four-hour groups through the eight-day period.

TABLE III

FOOD INTAKE OF EXPERIMENTAL GROUPS

		Days								Av. Calories per S for Days II–IX
		II†	III	IV	V	VI	VII	VIII	IX†	
4-Hour	Av. calories * per S per feeding	16	26	42	52	58	62	65	68	
	Cc. or grams	21	37	58	74	80	85	89	92	2,175
	Av. calories per S per day	65	157	251	314	347	374	391	272	
3-Hour	Av. calories per S per feeding	12	26	39	47	48	52	57	68	
	Cc. or grams	17	36	54	65	65	73	78	88	2,490
	Av. calories per S per day	71	205	312	376	383	418	454	271	

* Food intake is expressed primarily in calories rather than grams since there was a slight difference in the caloric value of human milk (.7 cal. per cc.) and the hospital formula (.9 cal. per cc.). Cubic centimeters or grams per feeding are also mentioned because of possible effect of bulk of food intake on activity (18).

† Day II, six feedings (9:00 A.M., 12:00 M., 3:00 P.M., 6:00 P.M., 9:00 P.M., 12:00 midnight) for three-hour group, four feedings (10:00 A.M., 2:00 P.M., 6:00 P.M., 10:00 P.M.) for four-hour group.

Day IX, four feedings for each group (3:00 A.M., 6:00 A.M., 9:00 A.M., 1:00 P.M., for three-hour; 2:00 A.M., 6:00 A.M., 10:00 A.M., and 2:00 P.M. for four-hour).

This table shows that there was a daily increase of food intake in both groups. From Day IV to Day IX the four-hour group took an

average of 5 to 10 calories more *per feeding* than the three-hour group. Their average *for the day*, however, was 50 to 60 calories less, since this group received six feedings per day whereas the three-hour group received eight feedings. From one point of view it might be argued that the three-hour group, having obtained more food up to Day IX, would be more prepared physiologically to wait four hours for feeding. Analysis of food intake on Day IX reveals, as stated above, that the caloric intake of the three-hour group was slightly less at both test feedings. At both the 9:00 and 1:00 feedings the three-hour group took an average of 65 calories, while the four-hour group took at the 10:00 and 2:00 feedings an average of 68 and 70 calories respectively. That a difference of five calories, however, is not sufficient to account for the difference in activity is shown in the fact that in these groups [6] there was no significant correlation between calories taken at a particular feeding and activity in the subsequent period. This correlation, computed for Days VI, VII, and VIII, was − .014 for the three-hour group, − .16 for the four-hour group. The slight difference in caloric intake on Day IX between the two groups is therefore insignificant in itself as a factor in the increased activity of the three-hour group.

2. *Weight and Activity.*—Although the two groups were equated for birthweight, the three-hour group gained on the average more than the four-hour. The gain over birthweight on Day IX was an average of 4 percent for the three-hour group, 2.2 percent for the four-hour group. It was found, however, that there was no correlation with activity of either weight itself or of increase in weight (within the weight range of the experiment). The possibility that the three-hour group, being on the average heavier on Day IX, might have needed extra food and might presumably have been more active in being forced to wait four hours for food, has therefore been ruled out.

3. *Diurnal Variability, Crying, etc.*—In addition to being consistently more active than the three-hour group up to Day IX, the four-hour group cried more frequently and showed crying periods of longer duration. Since crying was a concomitant rather than a cause of high activity, however, the increased crying in the three-hour group on Day IX could not be considered a causative factor in the increase of activity. There was also greater day-to-day variability in activity in the four-hour group, the rank order correlation of odd vs. even days being .59 ± .2 for the three-hour group, 0 for the four-hour. The variability shown in the four-hour group, however, never included as great a change as that shown by the three-hour group on Day IX.

[6] The method of feeding in this group, of course, prohibited real food deprivation.

Self-schedule [7]

When infants are permitted as far as possible to select their own schedule of feeding, how nearly does it approximate the three- or four-hour schedules imposed under hospital regime? Do they adopt a regular schedule? If so, does the regularity increase with age? Does the amount of food taken at a feeding determine the length of time elapsing before the infant becomes hungry again? Does the length of time since the last feeding determine the amount taken at the subsequent feeding? These are some of the questions which will be discussed in regard to the 'self-schedule' group.

Time between Feedings.—The mean time between feedings for Days II–IX for four infants who were under constant [*i.e.*, 24-hour] observation was 3.2 hours (σ 1.44). There was little variation between subjects, the averages for individual subjects being 2.9, 3.3, 3.3, and 3.6 hours. The length of time between feeding was longer at night than during the day, the average for day being 2.86 hours (σ 1.32), for night, 3.61 hours (σ 1.47). This difference is significant (C.R. = 4.1), and was consistent in every subject. Further evidence of this day-night difference is seen in the fact that there were 23 quiet periods [*i.e.*, periods between feedings] of over five hours' duration at night, only 5 during the day; and of the quiet periods of less than two hours' duration, 34 occurred during the day, 14 at night.

Although the *average* length of time between feedings showed no very significant variation over the eight-day period (3.48 hours for Days VI–IX vs. 3.38 hours for Days II–V), there were fewer very long and very short periods toward the end of the eight-day period and a greater number of three- and four-hour intervals. The number of quiet periods of five hours' duration or over was 17 for Days II–V, 11 for Days VI–IX, and the number of quiet periods of less than two hours' duration was 29 for Days II–V, 19 for Days VI–IX. Similarly the number of quiet periods of three to five hours' duration increased from 43 for Days II–V to 60 for Days VI–IX. This change probably indicates the beginning of a more regular feeding interval. There was a slight correlation between the length of the quiet period and the amount of food consumed at the previous feeding. The correlation computed for Days V–IX was highest (r = .69) in the infant who took the least food per feeding, lowest (r = .31) in the infant who took the most food per feeding. This probably means that after a certain minimum of food has been consumed, other factors besides food are more important in determining the length of the time between feedings.

[7] The results of the self-schedule group, as they apply more specifically to infant feeding, will be discussed in another publication.

A direct negative correlation ($r = -.91$) existed, as might be expected from the method of measurement employed, between activity in the quiet period and the duration of the quiet period. The lowest individual correlation ($-.55$) was found in the infant having the shortest average time between feedings. There was no correlation between amount of activity in the period preceding feeding and the amount consumed at the subsequent feeding. More surprising is the fact that there was no correlation between the length of the period between feedings and the amount taken at the subsequent feeding.

Activity within the Period.—Unlike the three- and four-hour groups, the self-schedule group showed no definite change during the eight-day interval in percent of half-minutes active during between-feeding intervals. The average in active half-minutes for Days II–V was 33.7 percent, for Days VI–IX, 34.3 percent. The eight-day average for the group, 33.9 percent, was slightly greater than that of the three-hour group, slightly less than that of the four-hour.

Number of Feedings.—The number of feedings per day averaged 7.3—fewer than the number for the three-hour group, who were fed eight times daily, more than for the four-hour, who were fed six times daily. Three of the four infants never took less than six feedings daily, the fourth infant on two days took only five. The variation was 5 to 10 feedings with a median of 7. Individual averages were 7.4, 7.9, 7.3, and 6.7 feedings per day.

Discussion

The above results indicate that the human infant does, within the first weeks of life, modify his behavior in accordance with the external demands imposed upon him by the culture into which he is born. Infants on a three-hour schedule 'learned' to be 'hungry' at the end of three hours, those on a four-hour schedule showed less definite, but certainly suggestive, evidence of having learned to wait four hours for feeding. A 'self-schedule' group, who had never been subjected to training on a regular schedule, showed little change in percent of activity in the inter-feeding interval, whereas the three- and four-hour groups showed a decrease in interfeeding activity toward the end of the eight-day period.

Results of the self-schedule group suggest that the most natural feeding interval for newborns is one which is variable, but on the average somewhat longer than three hours and shorter than four hours. The fact that the feeding intervals in this group tended to become more regular toward the end of the nine-day period is probably a sign of increasing physiological stability rather than an instance of learning.

The type of learning shown by the infants who 'learned' to be active or 'hungry' at the end of three hours does not, under the conditions of this experiment, lend itself to a detailed analysis. It appears to be a temporal form of conditioning set up according to the law of effect. When the three-hour infants were taken from their cribs at the end of three hours they ordinarily became immediately active and frequently cried. This behavior was present throughout the period of experimentation. The increase in activity, being reinforced by the feeding which immediately followed, gained in strength with each repetition, so that by the end of eight days it had become a conditioned response occurring at the end of three hours rather than later. There were no signs in the three-hour group of anticipatory conditioning [*i.e.*, of increased activity just before the end of the three-hour period]. If the above behavior had followed the pattern of an uncomplicated temporal conditioned response, however, the initial rise in activity in the fourth hour on the test day (Day IX) should have been followed by a period of quiet, since under the conditions of the three-hour schedule the infants were active only a few minutes before being fed. The reason for this imperfect pattern of the conditioned response probably lies in the physiological limits set by the organism for modification of behavior from without. Teaching an infant to be 'hungry' a little sooner than he would naturally awaken for food is not introducing a mode of behavior antagonistic to the primary food-seeking drive. Teaching an infant to wait for food, however (*e.g.*, establishing a five-hour schedule), would be much more difficult because such a situation would involve responses antagonistic to the prepotent drives determining the 'natural' hunger cycle. The fact that the infants on the four-hour schedule showed only suggestive evidence of having learned to wait four hours for food lends support to this hypothesis. Similarly the prepotence of sleep tendencies accompanying a full stomach would probably greatly impede or make impossible the artificial establishment of a 1.5- or 2-hour hunger cycle. Since in the present experiment the establishment of the three-hour activity cycle represented a facilitation rather than an inhibition of the food-seeking drive, the learning was not difficult to secure. The fact that activity persisted throughout the fourth hour on the test day instead of lasting a short time and then being succeeded by quiet, as would have occurred in a purely temporal conditioning situation, points to the prepotence of the hunger mechanism. The increased activity initiated and facilitated by the conditioning process, once set into motion, is maintained by the physiological mechanism of the hunger drive. This same facilitation by the conditioning stimuli also accounts for the fact that the fourth-hour activity shown by the

three-hour group was greater than that shown by the four-hour group at any time.

Evidences of learning in the four-hour group are, as stated above, only suggestive. The fact that the increase in activity before feeding time became more abrupt in relation to the time of feeding toward the end of the eight-day period and that coördinately the period of quiet sleep between feedings lasted longer, may indicate the presence of a temporal conditioning. The four-hour group unlike the three-hour was usually active before the end of the four-hour period in the crib, so that the actual lifting of the baby from the crib for feeding was not an important item in the initiation of activity. Until about Day VI the four-hour group had shown a rise of activity beginning about the end of the third hour. From Day VI on, the increase in activity became pronounced only at the end of three and a half hours. This may mean that the activity in the beginning of the fourth hour, never being reinforced by feeding, dropped out, whereas the activity at the end of the fourth hour, being consistently followed by feeding, was reinforced and thus maintained.

From a somewhat different point of view the behavior of the three-hour group when changed to a four-hour schedule might be described as an early frustration-aggression sequence. The infants had been conditioned to 'expect' food at the end of three hours. When they were deprived of the 'expected' food, their activity increased much beyond the limits which might have occurred if they had never built up this 'expectation.' The four-hour group in whom anticipation of feeding at the end of three hours had never been established, showed much less activity in the fourth hour. Freud has repeatedly emphasized the importance of early feeding reactions, and cites many instances of neurotic reactions in adults which had their foundation in the frustrating character of early feeding experiences. Dollard, Doob, Miller, Mowrer, and Sears (**3**, p. 60) also state that "frustration results automatically during the change of food habits," and that "this situation is engendered by our social patterns dealing with the learning of new food habits." Although the permanence, subsequent modifiability, and pervasiveness in terms of personality structure, of such early frustrations has not been experimentally investigated, the ease of their establishment, even in the newborn, is an important consideration.

The results of this experiment also have some significance in their relation to Kleitman's 'evolutionary theory' of the development of the sleeping-waking rhythm. Kleitman (**11**) distinguishes 'wakefulness of necessity,' a 'subcortical, probably hypothalamic function,' and 'wakefulness of choice,' a cortical function. The waking states of the newborn infant he believes to be 'wakefulness of necessity,'

the infant waking only when he is hungry, wet, cold or otherwise disturbed, falling asleep again after the disturbance is removed. 'Wakefulness of choice,' which results in a prolongation and modification of the sleep phase of the cycle, evolves from the 'wakefulness of necessity,' becomes established "in a gradual manner, when, and as, the development of the cerebral cortex, and of the distance receptors, widens the field of the animal's 'spontaneous' activity and increases the information concerning the outside world. With the increase in the number and variety of impulses reaching the cerebral cortex from the different sense organs, there goes a greater ability to profit by previous experience; and critical reactivity, characteristic of wakefulness of choice, makes its appearance" (**11**, p. 509). Granting that the eventual diurnal character of the sleep cycle is a "cortical phenomenon, individually acquired by training or experience" (p. 521), the data of the present experiment strongly suggest the conclusion that in infants, who lack a highly integrated cortical function, there must be some more primitive mechanism which serves as a means of adjusting the sleep cycle to the demands of the new environment. Since learning at a subcortical level has been repeatedly demonstrated, this conclusion does not seem illogical.

Summary

An attempt was made to find out whether human infants during the course of the first ten days adapt to [*i.e.*, 'learn'] a feeding schedule. Measurement, by automatic recording, was made of the bodily activity of three groups of infants during eight days of the period of their hospitalization after birth. Eighteen infants were on a four-hour feeding schedule, sixteen on a three-hour schedule, and four on a 'self-schedule,' determined by the crying of the infants. As a test of adaptation to the feeding schedule, the three-hour group was transferred to a four-hour schedule on the day before they left the hospital. The four-hour group served as a measure on Day IX (the test day for the three-hour group) of the activity pattern of infants who had been on a four-hour schedule from the beginning. The 'self-schedule' group served as an indication of what the 'natural' feeding rhythm of newborn infants might be under the conditions of the experiment. With food intake, weight change, etc., ruled out as contributing factors, the three-hour group, when changed to a four-hour schedule, showed a pattern of activity decidedly different from that shown by the four-hour group. Whereas the latter showed a gradual increase of activity which in the fourth hour became abrupt only towards the end of the four-hour period, the three-hour group showed an abrupt rise in activity at the end of three hours which

continued until feeding time. This increase was even more striking for the fact that, until the test day, activity in the three-hour group had been consistently lower than in the four-hour group. Results from the 'self-schedule' group suggest that on the average the most natural feeding rhythm for the neonate is one which is variable but which tends to involve feeding intervals somewhat longer than three hours but shorter than four hours. It is concluded therefore that the three-hour group had adapted to the three-hour schedule and showed signs of upset when a change of schedule was introduced.

The learning shown by the three-hour group is described as an instance of a temporal form of conditioned response set up according to the law of effect. It is suggested that the type of behavior demonstrated by the three-hour group represents an instance of the earliest form of human acculturation. Such a response pattern might also be described as an early frustration-aggression episode. The bearing of the experiment on Kleitman's evolutionary theory of the development of the sleep-waking rhythm is discussed.

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TONAL INTERFERENCE IN RELATION TO COCHLEAR INJURY [1]

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Tonal interference appears in the electrical activity of the cochlea as a reduction in the response to one tone due to the simultaneous presentation of another. In a previous report from this laboratory (**8**), this phenomenon was described and treated in its relations to other auditory processes. The present study is an attempt to obtain further information as to the nature and locus of the interference process. In this endeavor we employ as an analytical measure the injury which results from over-stimulation of the ear.

In the earlier investigation several characteristics of the interference phenomenon were recognized. The effect remains after elimination of the peripheral conductive mechanism up to the stapes, and therefore must have its locus somewhere between this mechanism and the place of formation of cochlear potentials. The process is allied to the transformation by which combination tones arise, for within limits the loss in interference represents a diversion of energy into these new components. Since interference reduces the amount of overloading, it is considered as separate from that process and prior to it. The relation to sensitivity is complex: interference seems to follow the principal factors that govern sensitivity, but to precede others which are located near the end of the series of cochlear processes and are characterized by their discrimination against the extreme frequencies.

Though the evidence already obtained makes it possible to refer the interference process to the more central portion of the sensory mechanism, and to locate it with respect to the other processes of transformation and overloading, the particular elements responsible for it have not been determined.

Over-stimulation of the ear provides a means for modifying the sensitivity of the ear through an injury whose locus is almost certainly known. In a number of experiments [2] it has been found that excessive stimulation causes a serious general loss of cochlear response. Correlated with this loss is a widespread injury to the organ of Corti. Over a broad area of the basilar membrane the sensory structure is disrupted, and the cells are found in formless masses at

[1] This investigation was aided by a grant from the Rockefeller Foundation.

[2] Report in preparation. See also Davis and others (**1**), and *cf.* earlier observations on stimulation deafness, reviewed by Kemp (**6**).

random regions of the cochlea. The degree and extent of injury depend upon the intensity of the sound and the duration of exposure. After grave exposure the loss of cochlear response may amount to 40 db or more, and the damage may extend over more than half the basilar membrane. After more moderate exposures, like those employed in the present study, the loss of response may amount to only 5 to 15 db, and in such cases the ordinary histological treatments do not disclose any damage. It is a resonable assumption, however, that the locus of the milder injury is the same as that of the extreme. The experiments will show the position of the interference process with reference to this locus.

Procedure

The general procedure followed that of the earlier study, to which the reader is referred for details. Guinea pigs were stimulated with pure tones from two audio-frequency channels, and the cochlear potentials were recorded with an electrode on the round window membrane. Measurements were made with a General Radio Type 736-A wave analyzer. Observations were made on ten ears, first under normal conditions and then after injury.

In our usual stimulating arrangement the tube which conveys the sounds from the speaker is terminated at a point 2.5 cm from the ear. This arrangement has the advantage of accuracy in calibration, but it yields only moderate intensities. For the larger degrees of injury, therefore, we have employed a system in which the tube is closely fitted to the meatus of the animal's ear. This closed-tube system was uncalibrated, and when it was used the readings of sound intensity were adjusted to conform to those obtained by the open-tube method.

Results

The previous investigation showed the effect of an interfering tone upon the intensity function for the cochlear response under normal conditions. The present observations include also the effect after injury. Figure 1 shows intensity functions for a tone of 1015~ under four conditions: alone and in the presence of a 3000~ interfering tone before injury, and the same after injury. The abscissa indicates in dynes per sq. cm. the intensity of the 1015~ stimulus, and the ordinate gives in microvolts the magnitude of the response at this frequency as selectively measured with the wave analyzer. The two curves to the left were obtained under normal conditions, and those to the right after the ear had been injured by exposure for 1 min. to a tone of 7000~ at an intensity of 30 dynes per sq. cm. The solid-lined curves represent the 1015~ tone in isolation, and the dashed lines the measurements made in the presence of the 3000~ interfering tone. The interfering tone was maintained at 1.8 dynes per sq. cm. both before and after injury.

The four curves are similar in type, in that all follow simple power functions over the principal portion of their course, and then depart from this form as overloading enters at high intensities. In

this animal the highest intensities produced only moderate overloading.

The curve on the left, for 1015~ alone before injury, has a slope slightly less than unity. The next curve, for 1015~ in the presence of the interfering tone before injury, has a somewhat steeper slope, very close to unity. Its distance below the simple function for 1015~ represents the interference effect. Here bending is delayed, so that in the region of overloading the curve approaches and finally merges with the simple function.

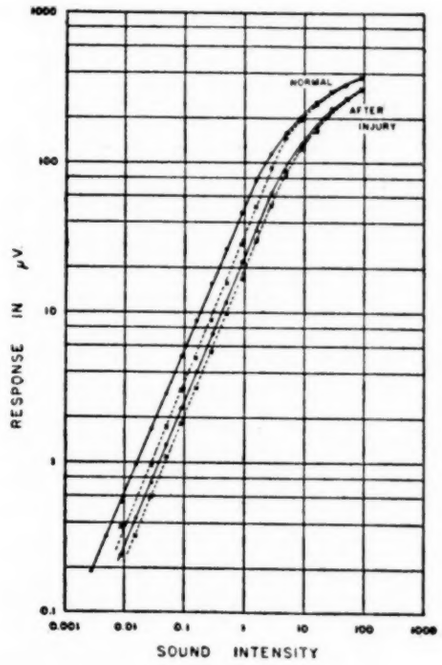

FIG. 1. Intensity functions for 1015~ alone and in the presence of 3000~, before and after injury. Guinea pig No. 403 L.

The third curve from the left represents the 1015~ tone alone after injury. Throughout most of its course this curve runs practically parallel to the first curve but about 8 db below it. At its upper end the difference is slightly less. The curve on the right represents the 1015~ function in the presence of the 3000~ interfering tone after injury. This curve bears a relation to the function for the 1015~ tone in isolation like that observed for the normal condition: it is slightly steeper than the simple function, and converges toward it in the region of overloading. The amount of interference, however, is significantly below that shown for the normal condition.

In the experiment illustrated the intensity was sufficient to produce only moderate overloading. Figure 2 presents results which show more fully the form of the functions when overloading is great.

As before, the abscissa indicates the intensity of the 1015~ stimulus, and the ordinate shows the response to this tone. The 3000~ interfering tone had an intensity of 6 dynes per sq. cm. before injury, and was raised to 28 dynes per sq. cm. after injury. This increase, however, was hardly sufficient to compensate for the effect of the injury upon the 3000~ tone; the sensitivity to this tone was reduced by about 14 db.

Below the region of overloading these results are similar to those of the preceding figure, though there are minor differences of slope and the changes of response due to interference and injury are greater. In the region of overloading, however, some new features appear.

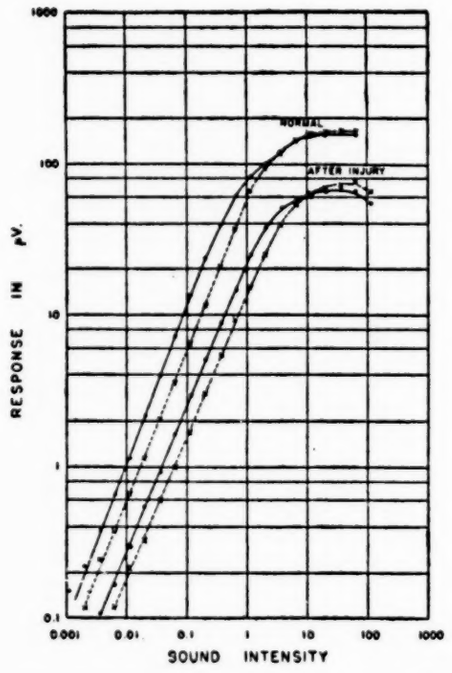

FIG. 2. Intensity functions for 1015~ alone and in the presence of 3000~, before and after injury. Guinea pig No. 404 L.

The simple and interference functions first approach one another, and then cross so that at the extreme intensities the interference condition gives a greater response than does the 1015~ tone alone. This feature is even more prominent after injury than before. Evidently interference affords a measure of protection against overloading both normally and after injury. When, as in this instance, the loss through overloading is great, it is possible for the interfering tone to afford a net gain in response. A somewhat similar result is obtained by tension upon the tensor tympani tendon (7), and indeed is to be expected of any measure which reduces the transmission of energy to the site of the overloading process.

The differences in the curves of Figs. 1 and 2 in the region of overloading bring out the fact that in this region the responses are un-

stable. The curves often alter their form, even within relatively brief times during observations on a given animal. A condition of instability is common for mechanisms that are worked near their physical limits; and experience has proved that the degree of overloading represented here is about the maximum that may safely be produced. Injury results when the intensity is carried much beyond the point at which the curves begin to bend downward. From limited observations we have the impression further that injury is particularly likely in the presence of a strong interfering tone. However, after some injury has already been caused it is possible, as was done in this case, to apply slightly greater intensities than normally without producing additional loss.

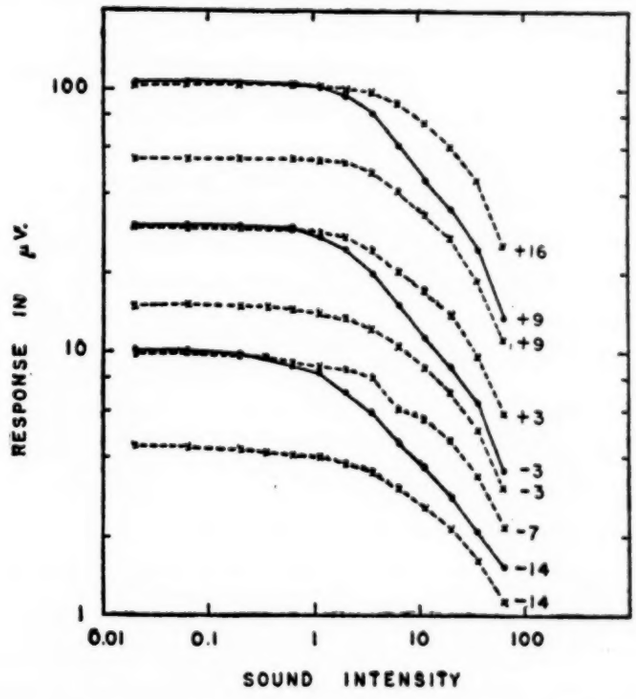

FIG. 3. Interference curves before and after injury. The intensity of the interfering tone was varied as indicated on the abscissa. Guinea pig No. 403 L.

In the preceding figures the intensity of the interfering tone was kept constant, while the intensity of the tone acted upon was varied. In the figures next to be presented the intensity of the tone acted upon was constant, and that of the interfering tone was varied. This procedure brings out the relation between injury and different degrees of interference.

Figure 3 gives results for an interfering tone of 3000~ when acting upon a tone of 1015~. The abscissa shows the intensity of the 3000~ tone, and the ordinate the magnitude of response to the 1015~ tone. The intensity of the 1015~ tone was constant for any given curve, but varied for the different curves. The numbers at the ends of the curves express these intensities in db with respect to 1 dyne per sq. cm.

The solid-lined curves are for the normal condition. Here 3 intensities of the 1015~ tone were selected to give response levels of 10, 30, and 100 μv when presented alone. As is usual, the interfering tone shows no effect at low intensities, and then as a sufficient intensity is reached the effect begins, and thereafter increases rapidly.

Results obtained after injury are shown by the dashed lines. Six intensities of the 1015~ tone were used, of which three were the same as before injury and three were such as to yield the same responses as before. The comparison of interference effects before and after injury thus may be made for equal stimuli or for equal responses.

Consider, for example, the two curves labeled '+9.' For all low values of the interfering tone these curves present a constant difference of about 6 db, which is also the difference before and after injury in the response to the 1015~ tone alone. As the intensity of the interfering tone reaches 1 dyne per sq. cm. an effect begins to be shown by the normal curve and thereafter the drop proceeds rapidly. The curve after injury shows an effect only after the intensity is carried somewhat higher, and its decline is always less rapid than that of the normal curve. It is plain that for given intensities of the interfering tone the interference is less after injury.

If now the comparison is made for equal response levels the same relation holds. If the solid-lined curve labeled '+9' is compared with the curve marked '+16,' it is noted that up to an intensity of 1 dyne per sq. cm. the curves are practically coincident. Beyond 1 dyne per sq. cm. the normal curve drops markedly below, and indicates correspondingly greater interference.

Similar relations are shown by the remaining curves of the figure, and the principle that interference is less after injury evidently holds regardless of the intensity or response level of the tone acted upon.

The above results have revealed the effect of injury upon the relation of interference to stimulus intensity. Next to be considered is the effect upon the relation to response level.

Figure 4 presents interference curves for 1015~ when acted upon by 3000~ as before, except that here the abscissa represents the response level of the 3000~ tone rather than its absolute intensity. This level refers to the response obtained for the 3000~ tone in isolation. The scale is in db with respect to a zero level of 10 μv; for example, '20' on the scale indicates that an intensity of the 3000~ tone was used which produced a response of 20 db above the zero level, or 100 μv. This intensity of course was greater after injury than before. Over most of the range, before overloading set in, the necessary increase of intensity after injury was fairly constant: it was 12 db at low levels and rose to 14 db as overloading began. It then increased rapidly to 38 db at the point of greatest bending of the

curves. (These functions for the 3000~ tone alone are not illustrated, but were similar to the simple functions of Fig. 2.)

As in the preceding figure, the solid lines represent the results before injury, and the broken lines the results after injury. Five levels were used for the 1015~ tone; these were obtained by presenting that tone at intensities indicated on the curves in db with respect to 1 dyne per sq. cm.

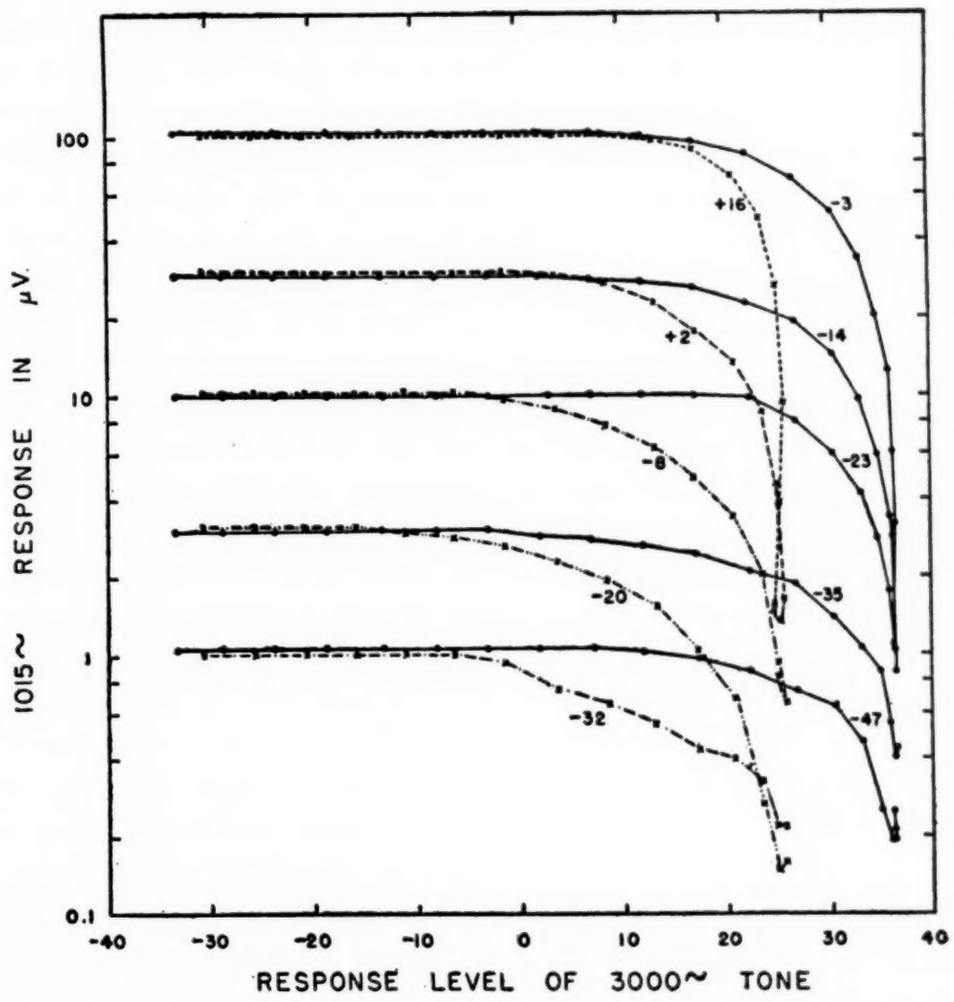

FIG. 4. Interference curves before and after injury, as a function of the response level of the interfering tone. Guinea pig No. 408 R.

The normal curves are generally similar to those shown in Fig. 3 except at the highest levels, where they fall more precipitously. The use of the response scale, as against the intensity scale of Fig. 3, has little effect over the principal range where the intensity function for 3000~ departed but little from linearity, but it greatly alters the picture in the region of overloading. For the normal condition, the 3000~ function remained straight up to a response level of 22 db, and had bent only slightly (less than 2 db) up to 30 db; while after injury the straight portion extended to 13 db and equally slight

bending up to 21 db. The portion of the scale to the right of these points thus represents a response that at first increased slowly with intensity, and finally declined. The decline was small, but careful inspection of the curves will reveal its influence: in many cases the last plotted value of response is slightly to the left of the one preceding it. The hooked ends shown by some of the curves have a different cause; they are due to the fact that for sufficiently great values of the interfering tone the response passes through a minimum, or in other words there is a limit to the interference effect. It may be mentioned further in this connection that for these extreme intensities of the interfering tone the responses show much instability, and usually vary unsteadily over ranges of 5 db or more. The values plotted represent roughly the midpoints of the observed variations.

The significant feature of this figure is the relatively great interference shown by the broken curves. Interference evidently is disproportionately great after injury when it is expressed in terms of response level. This difference is not due to overloading, as it is plainly shown in those portions of the curves to the left of the 13 db level, where overloading had not yet set in for either tone.

Plotting interference against response level, as was done in this figure, has the effect of compensating for the altered sensitivity to 3000~ as a result of the injury. If interference were simply a function of response level this procedure would give curves identical with those obtained before injury. The broken curves of the figure would then follow the corresponding solid curves. It is obvious that the compensation for impaired sensitivity has not equated interference and hence that interference is not a simple function of response level.

The evidence so far presented has been limited to one pair of stimuli, but similar results have been obtained for other pairs. The following figures show results for 11 tones over the range from 100 to 10,000~, all used as interfering tones during observation of the responses to a tone of 1015~.

In Fig. 5 the lowermost curve is the normal sensitivity curve, and shows, for each of the eleven stimulus tones given alone, the intensity required to produce a standard response of 10 μv. The intensity is represented on the ordinate in db with respect to 1 dyne per sq. cm. The next curve shows similarly the sensitivity after injury had been produced by a tone of 7000~. The third curve, marked '5 db loss-normal,' shows the intensity necessary, at each frequency indicated, to produce 5 db of interference upon the 1015~ tone, before injury. For these measurements the 1015~ tone was presented at the intensity which gave for it in isolation a response of 10 μv. The uppermost curve shows similar results obtained after injury.

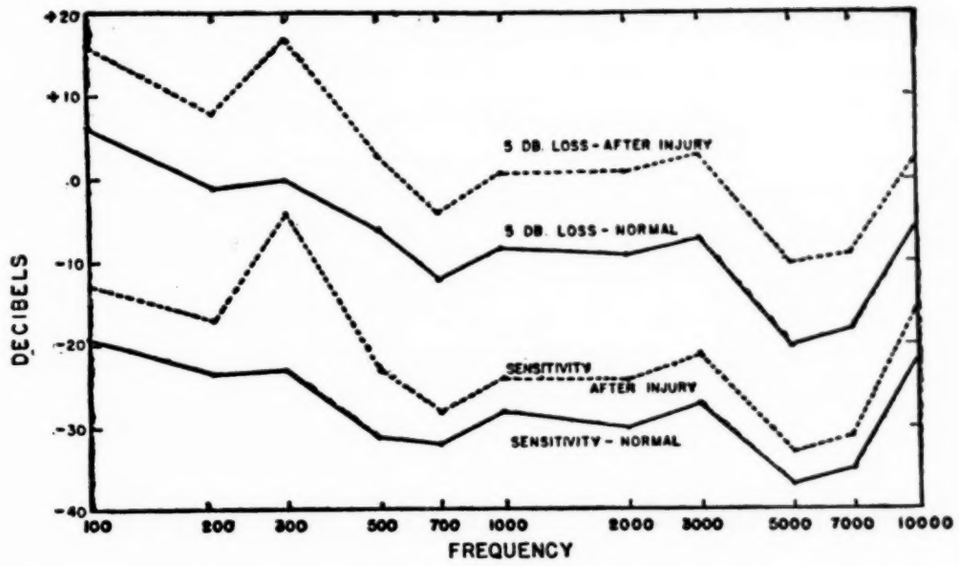

FIG. 5. Sensitivity and interference functions, before and after injury. Guinea pig No. 403 L

A comparison of the two sensitivity curves reveals that the injury was general, though by no means equal throughout the range. The greatest impairment was at 300~, which is remote from the frequency that produced the injury. The large effect at 300~ is unusual; in most cases the change in sensitivity was more nearly uniform throughout the range. In no case have we found any selective impairment at the frequency of the injuring tone.

A comparison of one of the interference curves with its corresponding sensitivity curve shows a close similarity of form. This relation holds after injury as before. A striking illustration is af-

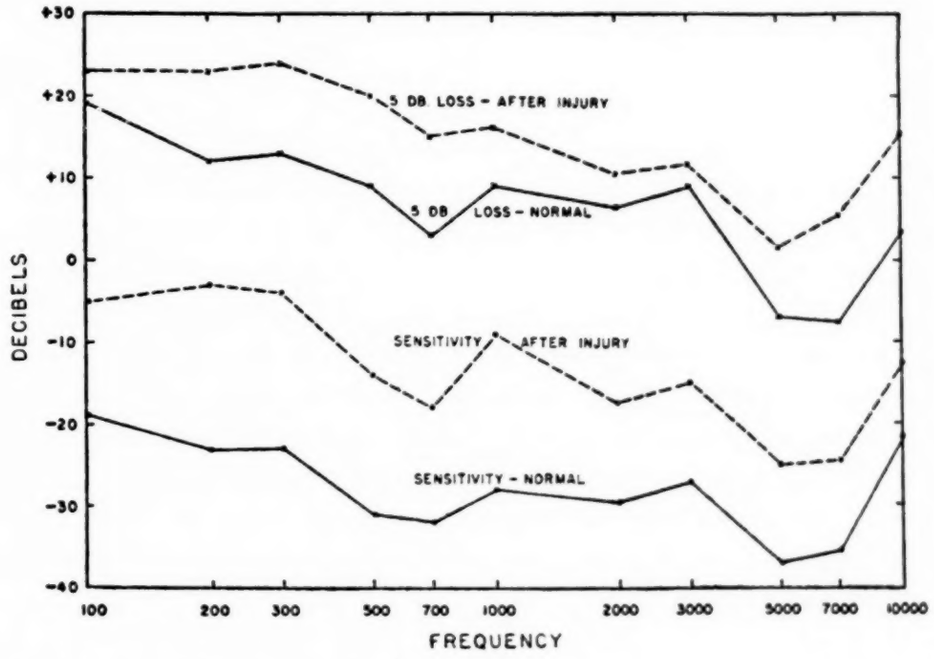

FIG. 6. Sensitivity and interference functions, before and after injury. Guinea pig No. 403 R.

forded by the large loss at 300~, which is reflected in the corresponding interference measurement. Thus the earlier observation of a functional dependence of interference upon sensitivity is confirmed (**8**).

In some instances, as when more serious injury is produced, the similarity of interference and sensitivity curves after injury is less precise. Figure 6 shows results of this kind. Injury was produced with 300~ at 200 dynes per sq. cm. for 4 min. The upper curve, which represents the 5 db interference effect after injury, follows the general course of the curve of sensitivity after injury, but it exhibits somewhat smaller variations. This difference perhaps is due to the fact that the relation between sensitivity and interference is not a simple one, and that injury affects sensitivity by altering not only the factors that are common to the two, but also those that follow the interference process.

Discussion

Logically, we distinguish three possibilities for the location of the interference process relative to the place of injury. It may precede the injury, or follow the injury, or occur at the same site. For either of the first two possibilities the processes must be distinct; but for the third they may overlap wholly or only in part. Let us consider these possibilities in turn.

1. We can imagine several points at which interference might arise before the stimulus reaches the hair cells of the organ of Corti. It could appear in the movements of the stapes, if this member fails properly to follow the movements imposed by the earlier portion of the ossicular chain. It could appear in the cochlear fluids, either because they are compressed unduly, or, more likely, because the presence of various soft tissues and yielding walls allows the escape of energy. It could appear in the movements of Reissner's membrane if it plays a pertinent role in transmission, as some have claimed (**2**), and it fails to respond linearly to the forces imposed upon it.

If interference appeared at any of the points mentioned, it should not be affected by an injury which involves the organ of Corti but none of the more peripheral structures. As no change will appear in the stimuli brought to its site, the interference process must proceed as before. Of course, since injury now intervenes between that process and the production of cochlear potentials, the interference effects must be observed through a reduced level of response. The functional relation with stimulus intensity, however, will undergo no change of character.

Figure 3 shows, on the contrary, that after injury the form of the interference function is altered. The two curves marked '+9,'

for example, are not of the same shape. Similarly, the two top curves fail to coincide, as they should if interference were peripheral to the injury. This last point involves the consideration, based on the form of the intensity functions as shown in Fig. 1, that interference is practically independent of the intensity of the tone acted upon, provided that this intensity is not so strong as to involve overloading.

The conclusion drawn regarding the order of interference and injury in the cochlear processes remains in force even apart from the assumption that injury occurs in the organ of Corti. If this assumption is denied the evidence still shows that interference can not be peripheral to the locus of injury.

2. We now consider the second possibility, that interference follows injury. That interference arises at some point beyond the organ of Corti is rather difficult to conceive in concrete terms. Such a location would force us to the view that the cochlear potentials also arise beyond the organ of Corti, whereas abundant evidence, especially that derived from the study of albino cats and Dalmatian dogs (**3, 4, 5**), indicates that the hair cells are the source of these potentials. Thus it would seem more reasonable, if this second possibility were to be developed, to deny that injury occurs in the hair cells, and refer it to some part of the conductive mechanism.

In any case, however, this possibility is excluded by the results. If interference occurred beyond the site of injury it should be a simple function of response level, at least in the absence of overloading. Its process should suffer from the injury in the same way as that giving rise to the cochlear potentials. Therefore, after compensation for the loss of sensitivity, as indicated in Fig. 4, the results should be identical with those before injury. It is obvious that such is not the case.

3. By elimination we are brought to the third possibility, that interference and injury occur at the same place, in the organ of Corti. All the evidence points to the reasonableness of this view, and suggests that the hair cells themselves are the essential elements. After the action of an intense stimulus the destruction of hair cells is widespread; and, as the present results show, the effects upon sensitivity and interference are general.

Sensitivity and interference are both changed by injury, but usually not in equal degree. At times the loss of sensitivity is the greater, and at other times the change in susceptibility to interference is the more marked. These variations are not surprising in view of the complexity of the relations of the two. They follow different functions with respect to stimulus intensity, and may be affected by overloading to different extents. Moreover, the various hair cells that are included in the response to a given stimulus will probably

not be operating on similar portions of their intensity and interference functions, and injury to some of them may easily have a differential effect.

Conclusions

Tonal interference has its locus in the hair cells of the organ of Corti. This conclusion is reached on the basis of considerations summarized below:

1. After injury to the cochlea by over-stimulation the interference produced by a given tone is less, even though we may compensate for the lowered level of the responses for the tone acted upon. Therefore interference does not precede the injury process.

2. If, after injury, a compensation is made for the lowered sensitivity to the interfering tone as well as for that to the tone acted upon, the amount of interference is greatly exaggerated. In other words, a given stimulus after injury produces greater interference than one at the same response level before injury. It follows that interference cannot be a distinct process beyond the site of injury, as beyond that site the compensation will afford the same strength of stimulus after injury that existed there before.

3. Interference and sensitivity are both affected by injury. The forms of their frequency relations are similar after injury, just as they are before.

4. Histological studies show that the impairment of cochlear response caused by over-stimulation is correlated with a widespread disruption of the organ of Corti. As the hair cells are indicated as the source of cochlear potentials, they are regarded as the specific elements whose partial loss and impairment occasion both the reduction of sensitivity and the change in the interference process.

5. Interference and sensitivity are not necessarily altered in equal degree by injury because they do not wholly overlap. Sensitivity reflects all features of the action process up to the formation of cochlear potentials, but interference includes only those up to its own site. The action in the hair cells evidently is complex, and processes appear beyond interference which modify the sensitivity function.

6. One of the processes beyond interference is overloading. This position of overloading is indicated by the fact that it is reduced by an interfering tone. The effect occurs after injury as before.

The present results fortify earlier conclusions regarding the order and loci of events in the ear. The events are (1) peripheral conductive processes, (2) transformation, (3) interference, (4) overloading, and (5) generation of electrical potentials.

The peripheral conductive processes extend from the entrance of sound waves into the meatus to their impingement upon the hair

cells. Transformation and interference are closely related, and both are probably early hair-cell processes. Overloading is a late hair-cell process, while the generation of cochlear potentials is the terminal one under the conditions of observation. Each process has its own characteristics, and reflects those of the processes which precede it. Sensitivity is an over-all function, subject to analysis in limited degree.

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THE RETENTION OF A CONDITIONED OPERANT RESPONSE [1, 2]

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A previous study (4) has described the method and results of an experiment dealing with the measurement of acquisition, extinction, and spontaneous recovery of a conditioned operant response in the white rat. These data may be gathered within the space of a single experimental session lasting not more than two hours, during which time forgetting presumably influences the measurements negligibly. However, a considerable loss in retention may be expected when durations of the order of a day and longer intervene between successive runs. The present experiments have been designed to measure the magnitude of this loss.

The apparatus employed is a simple elevated runway with a starting box at one end and a food box at the other end. The response of traversing this runway from the starting box to the food box is measured by its 'latent period'; this is defined as the time required for the rat to leave the starting box. The course of acquisition of this response is determined in a given number of equally spaced trials with a piece of food of constant size in the food box at each trial; extinction is carried out in a similar manner with food absent from the food box. A first experiment reported in the present paper deals with the measurement of re-acquisition following 24 hours after an original acquisition of 15 trials and an extinction carried to the point of a latent period of 3 minutes or more. A second experiment is concerned with the measurement of re-acquisition following at periods of 3, 7, 14, and 28 days after an acquisition carried to a criterion of three successive responses with latent periods of 5 seconds or less.

The retention of many kinds of learned responses has been studied over a period of many years. A review of these studies is given by Hunter (7). The classical curve of forgetting, which applied to nearly all types of learned responses, is typically a curve of negative acceleration, which shows that the rate of forgetting decreases as time proceeds. In contrast to this is the striking fact that condi-

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[2] The author is indebted to Professor C. H. Graham of Brown University, under whose direction the present research was carried out.

tioned reflexes of the conventional type have often been reported to exhibit nearly perfect retention over long periods of time. In many of the cases reported, this may be due to the fact that the original responses have been greatly 'overconditioned.'

Many of the earlier studies on the retention of Pavlovian conditioned reflexes are summarized in two articles by Razran (**13**, **14**). More recently, Liddell, James, and Anderson (**10**) have found that a conditioned leg flexion to shock in sheep exhibits considerable retention after a period of two years. Hunter (**8**) found only slight forgetting of the conditioned running response of rats on an octagonal grill, when the response was measured 30 days after an original conditioning and extinction. Schlosberg (**16**), however, reports that conditioned responses to tail-shock in rats show some loss of frequency and amplitude during 24 hours, and complete loss after 2 months. Marquis and Hilgard (**11**) report 100 percent retention of the conditioned eyelid response in one dog after 33 days, and a 60 percent retention after 6 months. Kellogg and Wolf (**9**) obtained good retention of the conditioned foreleg flexion in dogs after intervals up to 6 months. Complete retention of the human pupillary response conditioned to subliminal auditory stimuli seems to have been obtained by Baker (**1**) after periods up to 16 months.

In a study of the retention of human conditioned eyelid responses made by Hilgard and Campbell (**5**), intervals of 1 day, 1 week, 4 weeks, 8 weeks, and 20 weeks were used. Retention was measured by two methods: (*a*) by comparing the amplitude of the last 5 conditioning trials with the amplitude on the 5 reinforced test trials occurring after the interval; and (*b*) by comparing the amplitudes of responses in the last 10 conditioning trials with those in the first 10 reconditioning trials. With the first method, the amount of retention remained at 50 percent and above for all the intervals used. According to the second method, the results show nearly 100 percent retention for all intervals.

Wendt (**18**) reports the case of a dog which showed a high degree of retention for a conditioned leg flexion. Retention was measured two and one-half years after the original training. During the last 30 trials of conditioning the response occurred with a magnitude of 5 mm. On the retention test, the response had an average mangitude of 21.5 mm and occurred after 16 out of 20 stimulations spaced at 1-minute intervals.

Hilgard and Humphreys (**6**) established conditioned eyelid discriminations to illumination changes in human subjects. Retention of both positive and negative responses was measured in different groups of subjects after intervals ranging from 4 to 19 months. As measured by the percent frequency of response, retention showed no

loss, and in some cases a slight increase, throughout these periods of time.

Conditioned salivary responses to single lights and to patterns of lights were established in human subjects by Razran (**15**). The magnitude of the response was measured after 1, 2, 4, 8, and 16 weeks, and a gradual loss of retention was noted. After 16 weeks the responses to single stimuli had nearly disappeared, while responses to patterns were reduced by two-thirds. An interesting result is that the data do not describe a curve of forgetting which has steep negative acceleration. Expressed as percentage reduction in original conditioning to a single stimulus, the amounts of forgetting after 2, 4, 8, and 16 weeks were found to be 13, 46, 77, and 92 percent respectively.

In a recent experiment Brogden (**2**) tested the retention of conditioned leg flexion in dogs after a period of 6 months. In one group of four animals, the flexion response was reinforced by food for 1000 trials. The response in two other animals was reinforced by shock for 1000 trials. Retention was measured in the two groups by an extinction series conducted 6 months after the final reinforcement. The retention of the response in those animals having shock reinforcement was found to require a mean of 300 trials for extinction, whereas extinction was completed in 140 trials for the response reinforced by food. A significant difference was found to obtain between these averages.

The problem of reconditioning after extinction has a less extensive history. It is reported by Pavlov (**12**) that successive series of reconditionings following alternate extinctions of a conditioned salivary response require fewer and fewer trials, while extinction becomes more difficult to establish. According to the results of Skinner (**17**) with the conditioned lever-pressing response, curves of reconditioning and reëxtinction following extinction exhibit the same rates as those of original conditioning and extinction. The number of trials required for the two effects was not compared in this experiment. Skinner (**17**, p. 94) reports an experiment by Keller, showing that the effects of extinction influence a second curve of extinction taken forty-five days later. The second curve is shallower than the original [*i.e.*, fewer responses were required for complete extinction]. According to Skinner, this result is evidence that the rats have not 'forgotten' the extinction.

At the present time it is difficult to make a general statement concerning the retention of conditioned responses. The weight of the evidence seems to support the conclusion that conditioned reflexes are extremely resistant to forgetting. However, a number of important considerations must be clarified before this conclusion can

be accepted fully. More experiments are required on the problem of retention after varying degrees of original conditioning.

Apparatus and Procedure

The apparatus used in this experiment, and described previously (4), is a simple elevated runway having a starting box at one end and a food box at the other end. The unconditioned stimulus is a small pellet of dog chow weighing 0.04 grams. The conditioned response required of the rat is the traversing of this runway, after a door in front of the starting box is opened, from the starting position to the food box. This response is measured by its latent period, which is defined as the time taken by the animal to leave the starting box after the door has been opened. The latent period is assumed to be an inverse measure of response strength. A more complete description of the general procedure is given in the previous account.

The subjects in the present experiment were 16 white rats whose average age was 2½ months when the study was begun. These animals had taken part in an experiment on external inhibition and disinhibition (3). Fifteen trials of acquisition were conducted, and extinction was carried to the criterion of a response with a latent period of 3 minutes or more. Trials were spaced at the constant interval of 75 seconds. The data from this experiment reveal a close correspondence between the curves of acquisition and extinction for the experimental and control groups, except on trials following the application of extra stimuli. It is assumed that the phenomena of external inhibition and disinhibition, which appear on single trials of acquisition and extinction, had no appreciable effect upon the measurements reported in this paper.

Following extinction to the 3-minute latent period criterion, the experiment was terminated and the animal placed in the food box and allowed to eat for ten minutes. A second curve of acquisition was obtained 24 hours later. Trials were again spaced at 75 seconds. Measurement was continued until the response attained a level in which the latent period was less than 5 seconds for three consecutive trials. This criterion assured that the response was of a magnitude comparable to that obtained in fifteen reinforced trials of original conditioning.

In random order, the animals were now divided into four equal groups. Retention was measured by obtaining a curve of reconditioning in one group 3 days after the second conditioning; in another, the interval was 7 days; in a third, 14 days; and in a fourth group, 28 days. The animals spent this intervening time in ordinary living cages, well supplied with food. The food was removed 36 hours before the reconditioning test was to be given. In this test the conditions of reinforcement and the interval between trials were the same as in the original conditioning session. Acquisition was continued until the latent period of the response was 5 seconds or less on three consecutive trials.

The above procedure enabled the measurement of three factors: (1) the amount of spontaneous recovery which takes place 24 hours after extinction to a criterion of a 3-minute latent period; (2) the course of reconditioning following extinction; and (3) the course of retention from the period of 3 days to the period of 28 days.

Results

The average logarithm of the latent period for 16 rats on each trial of reconditioning after extinction, and for four groups of four rats each on each trial of reconditioning after periods of 3, 7, 14 and 28 days, is given in Table 1. The average deviation of each log value is also included.

Spontaneous Recovery.—Twenty-four hours following extinction to the criterion of a 3-minute latent period, the average log latent period of the response is 1.47 (30 seconds). A previous study of spontaneous recovery (4) has shown that the response is rapidly recovered in the first few minutes following extinction to the same criterion. After one minute the value of log latent period is 2.01 (102 seconds), and

TABLE 1

THE AVERAGE LOGARITHM OF THE LATENT PERIOD ON EACH TRIAL OF RE-ACQUISITION CONDUCTED 24 HOURS AFTER EXTINCTION FOR 16 RATS, AND ON EACH TRIAL OF RE-ACQUISITION FOLLOWING THE SECOND CONDITIONING AT INTERVALS OF 3, 7, 14, AND 28 DAYS FOR 4 GROUPS OF 4 RATS EACH

Trial	Interval after Extinction 1 Day		Intervals after reconditioning							
			3 days		7 days		14 days		28 days	
	Log *P*	A.D.log *P*	Log *P*	A.D.log *P*	Log *P*	A.D.log *P*	Log *P*	A.D.log *P*	Log *P*	A.D.log *P*
1	1.47	0.20	1.06	0.15	1.10	0.13	1.46	0.28	1.83	0.11
2	1.18	.20	0.76	.23	0.90	.32	1.17	.12	1.29	.20
3	1.15	.25	0.49	.34	0.77	.19	1.11	.33	1.13	.20
4	1.05	.29	0.46	.42	0.72	.37	1.07	.41	1.16	.29
5	0.93	.20			0.54	.20	1.10	.16	1.12	.23
6	0.77	.28			0.37	.25	0.89	.16	1.08	.18
7	0.69	.30			0.36	.19	0.80	.24	0.93	.33
8	0.57	.36					0.85	.33	0.76	.34
9							0.68	.37	0.78	.27
10							0.62	.27	0.71	.12
11							0.52	.35	0.60	.15
12									0.63	.32

drops to 1.57 (37 seconds) after 6 minutes. At ten minutes the log latent period value is 1.54 (35 seconds), a figure which indicates that a very small increase in spontaneous recovery takes place between six and ten minutes.

The results of the present experiment show that the amount of spontaneous recovery of the response taking place between 10 minutes and 24 hours following extinction is very slight. The amount is measured by the difference in the log latent period values of 1.54 (35 seconds) after ten minutes, and 1.47 (30 seconds) after 24 hours. Obviously the latter value must be influenced to some extent by the process of forgetting.

Reconditioning after Extinction.—The course of reconditioning after extinction is illustrated in the graph of Fig. 1. For purposes of comparison the curve of original acquisition for these sixteen rats is drawn as a lighter line. The reconditioning curve begins with an average log latent period of 1.47 (30 seconds) and attains a value of 0.57 (3.7 seconds) on the eighth acquisition trial. The curve fitted by inspection through the experimental points is almost a straight line, although it would be expected to exhibit negative deceleration on trials following the eighth, as it approaches an asymptotic value. The initial slow and nearly constant rate of re-acquisition is to be contrasted with the curve of original conditioning which has a most rapidly changing slope during the first three or four trials of acquisition.

Our results show that eight trials were required for the latent period to reach a value comparable to that of the fifteenth trial in original acquisition. In this respect the data are in agreement with those of Pavlov on the conditioned salivary response, which show reconditioning following extinction to be accomplished in fewer trials than original conditioning. However, it is to be observed that the rate of reconditioning is slower than that of original acquisition, at least until the fourth trial is reached. This might seem to reveal the effect of extinction on the course of reconditioning. In an ex-

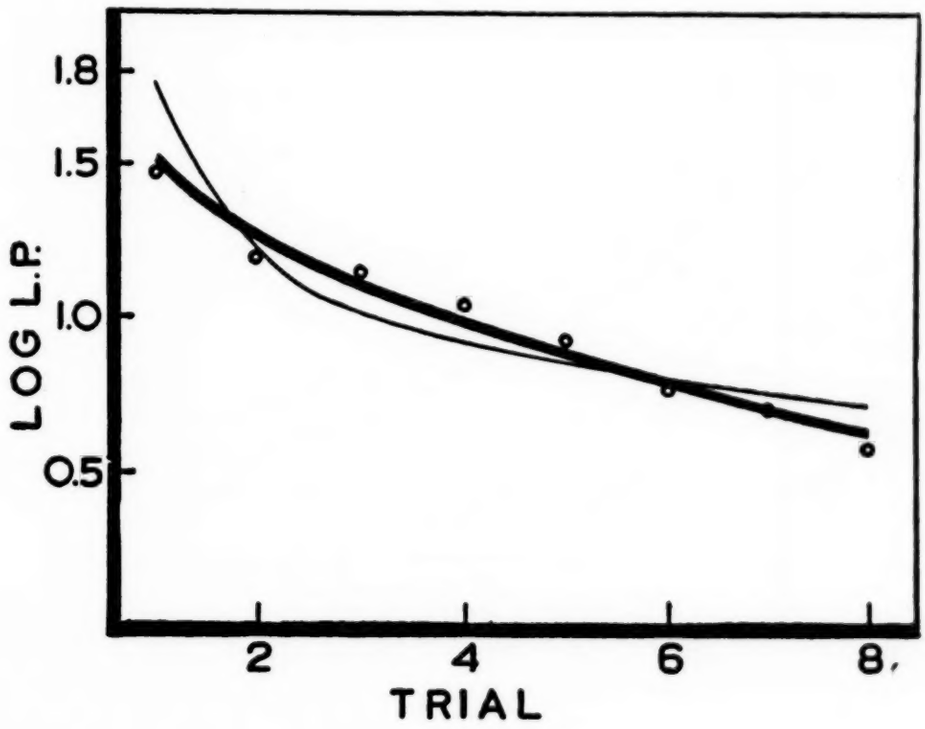

FIG. 1. The curve of re-acquisition, obtained from a group of 16 animals, 24 hours following extinction to a criterion of a 3-minute latent period. The heavy curve is fitted by inspection to the experimental points. The light curve represents the course of original acquisition in these animals.

periment performed by Keller and reported by Skinner (17) the retention of the effects of extinction was shown in a curve of extinction taken after 45 days. It may be supposed that the retention of extinction after one day has, in our experiment, slowed up the rate of re-acquisition.

Retention.—The 16 animals, in which reconditioning had been carried to a criterion of 3 consecutive trials with log latent periods of 5 seconds or less, were now divided into 4 groups. A curve of re-acquisition was obtained with each group at an interval of 3, 7, 14, or 28 days after the conditioning which followed the original extinction. The results obtained are shown in Table 1 and Fig. 2. After 3 days, the curve of acquisition begins with a log latent period value

of 1.06 (12 seconds) and proceeds rapidly to a value of 0.46 (2.9 seconds) on the fourth trial. After 7 days, the curve of reconditioning begins with an average log latent period of 1.10 (13 seconds) and reaches the value of 0.36 (2.3 seconds) on Trial 7. In the third group of animals, tested after 14 days, the log latent period on the first trial of acquisition is 1.46 (29 seconds) and on the eleventh, 0.52 (3.3 seconds). After a 28-day interval, acquisition starts with a value of log latent period of 1.83 (68 seconds) and attains a value of 0.63 (4.3 seconds) on the twelfth trial.

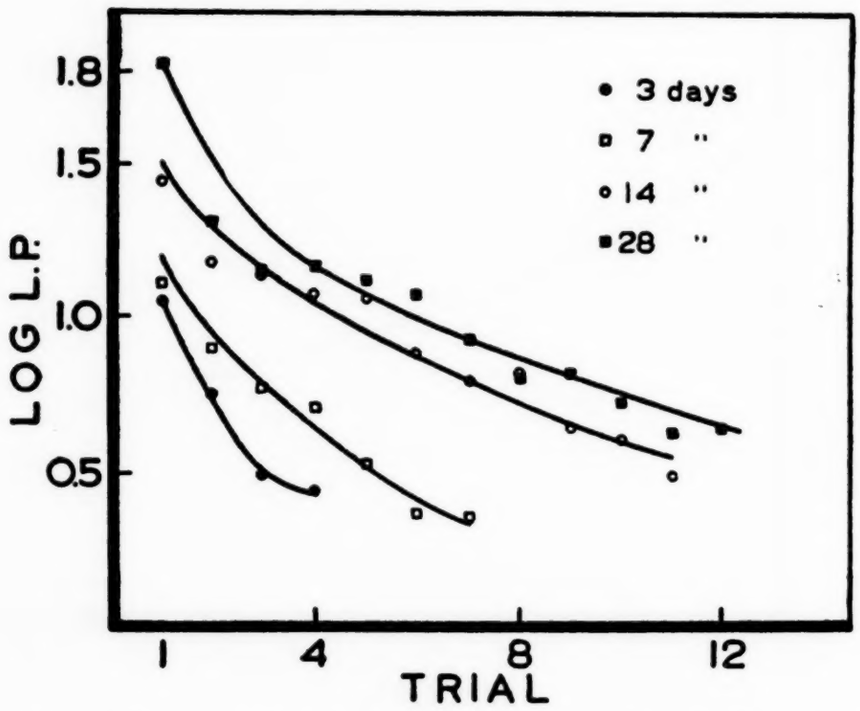

FIG. 2. Curves of re-acquisition obtained from 4 groups of 4 animals each at periods of 3, 7, 14, and 28 days after an acquisition which followed original extinction. The curves are drawn by inspection through the experimental points.

It is interesting to note that these curves of re-acquisition have a more gradual slope on the first four or five trials than is the case with original acquisition. This is especially apparent in the curve for the 28-day group, which begins acquisition with a latent period comparable to that shown in original conditioning, but proceeds at a slower rate for the first few trials. This decrease in rate may be produced by retention of the effects of previous extinction, although it is hard to believe that these would persist for 29 days.

Figure 3 shows retention for the various intervals employed, as measured by (1) number of trials required to reach the criterion of 3 successive responses of less than 5-minute latent period, and (2) the value of log latent period on the fourth trial of re-acquisition. Both curves are of the same negatively acclerated shape throughout.

The curve of retention for the response under investigation is similar in its negatively accelerated form to the classical curve of retention, although the latter usually exhibits a steeper initial slope. Our results show that forgetting is approaching completion four weeks following original acquisition. This finding is to be contrasted with several investigations on the Pavlovian type of conditioned response, which have shown nearly complete retention over periods of months. However, Schlosberg's (**16**) results and the study of Razran (**15**)

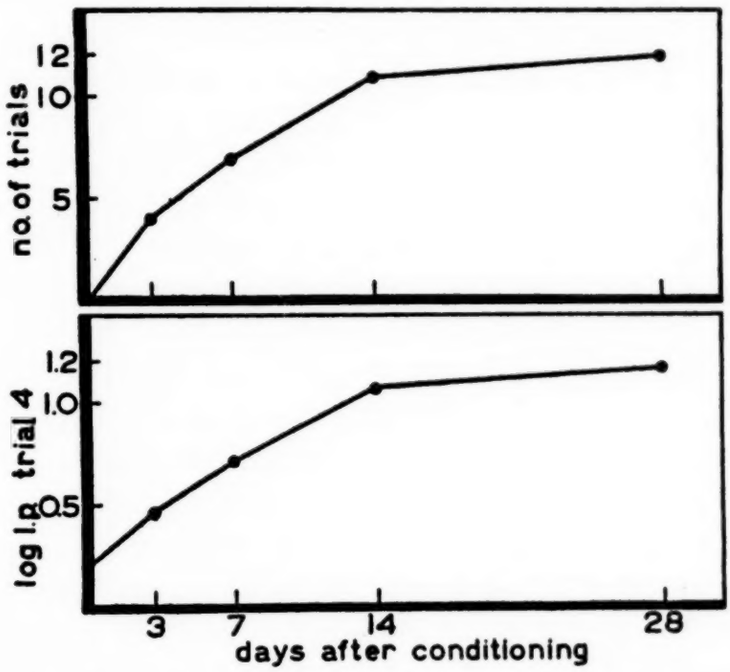

FIG. 3. Amount of retention after periods of 3, 7, 14, and 28 days, as measured by (*a*) number of trials of re-acquisition required to reach a criterion of 3 consecutive responses having latent periods of 5 seconds or less; and (*b*) the value of log latent period on the fourth trial of re-acquisition. Each point represents an average obtained from 4 animals.

have demonstrated considerable forgetting of this type of conditioned response. The course of retention indicated by Razran's data is similar to that found in the present investigation. Further research is needed to determine the role that the factors of overlearning and differences in retention criteria play in the determination of the reported results on conditioned reflexes.

SUMMARY

1. An experiment is reported in which the reconditioning of a conditioned operant response was measured 24 hours following extinction. The conditioned response involved the running of a simple elevated runway by a white rat, from a starting box at one end to a food box at the other end. The measure of response employed was the latent period. This is defined as the time required for the rat to leave the starting box after the door is opened.

2. A curve of reconditioning was obtained for a group of 16 white rats, 24 hours following a session including acquisition for 15 trials and extinction to the criterion of a latent period of 3 minutes or more. The course of re-acquisition was measured in each rat until the criterion of 3 successive responses with latent periods of 5 seconds or less was reached.

Spontaneous recovery 24 hours after extinction is revealed by a log latent period value of 1.47 (30 seconds) on the first reconditioning trial. This value is only slightly less than one obtained (4) for a time interval of 10 minutes after original extinction.

The curve of re-acquisition following extinction proceeds as a nearly straight line to a log latent period of 0.57 (3.7 seconds) after 8 trials. The rate of reconditioning is slower on the first 4 trials than the corresponding rate of original acquisition. This may represent the influence of retained extinction effects.

3. The 16 animals on which reconditioning after extinction had been measured were divided into 4 groups of 4 rats each. Acquisition was again measured in the 4 different groups after periods of 3, 7, 14, and 28 days. Curves of re-acquisition show that 4, 7, 11, and 12 trials respectively are required at these different intervals in order for the response to reach a level of strength represented by a latent period of 5 seconds or less for 3 consecutive trials. Curves of retention show the increase with time for forgetting of (*a*) number of trials required to reach the 5-second criterion, and (*b*) log latent period on the fourth trial of re-acquisition. Both curves exhibit negatively accelerated form. These data are compared with results dealing with the retention of Pavlovian types of conditioned response.

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INDIVIDUAL DIFFERENCES IN THE AUTOKINETIC PHENOMENON *

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In some of the more recent investigations of personality structure, experimental procedures have been emphasized which approach the demands set by an objective scientific method. Among such experiments of particular interest to us in our investigation was one initiated by McDougall (**16**) and continued in further experimental studies by Guilford and Braly (**10**), and by Hunt and Guilford (**13**). McDougall advanced the theory that the speeds at which nervous impulses travel, especially in the higher centers, differ in individuals, and that this difference might account for greater or lesser overt behavior. To test this assumption he and the other investigators used fluctuating ambiguous figures in the form of windmill shadows or reversible cubes. The rate of change of perspective of these figures furnished the criterion for introversion and extroversion, the former being assumed capable of a greater number of changes per given time. Hunt and Guilford used the Wheatstone cube in an experiment with psychotic patients and found that manic-depressive patients observed a definitely slower rate of reversal of the cube's perspective than did dementia præcox patients.

This ability to produce fluctuations in ambiguous figures points toward a unique capacity in certain individuals to restructure the perceptual field more or less according to their own subjective standards. Somewhat similar capacities and individual differences are brought to light through the autokinetic phenomenon. This phenomenon is visual in character and can be experienced by observing a stationary pin-point light from a little distance in a totally dark room. It manifests itself by lateral movement of the light in various directions and at various speeds, depending on the individual, and is obviously subjective in nature. The differences among individuals in the amount of movement seen, ranging from no movement to an extensive amount, are markedly greater than have been found in ordinary distribution of sensory phenomena and hence can well be taken as a measure of notable differences in individuals. We believe that the autokinetic phenomenon offers some distinct advantages

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[1] Traditionally with the psychological laboratories of the University of Kansas. The writer expresses his indebtedness to Dr. J. F. Brown for direction of this study, and to Dr. R. H. Wheeler and other members of the psychology staff for many valuable suggestions.

over the tests with ambiguous figures in that there is greater possibility of variability in response, and less probability of perceptual distraction.

The illusion of movement of a small light in a dark field was scientifically observed as early as 1799 by Von Humbolt (**20**) who called it Sterne Schwanken—star wavering. Since then it has been investigated by Charpentier (**8**), Exner (**9**), Aubert (**3**), and others; more recently by Carr (**7**), Adams (**1**), Hovland (**12**), Guilford and Dallenbach (**11**), Shilder (**18**), and Sherif (**17**). Aubert discovered the phenomenon independently of Charpentier and called it Autokinetische Empfindung—autokinetic sensation. Hovland and Sherif give good recent discussions and summaries regarding the phenomenon. In general the amount of autokinetic movement observed, the patterns and general characteristics reported in the past, have varied somewhat with different investigators. Theories regarding the illusion have equally varied, ranging from explanations centering around local eye functions to those emphasizing extensive body tensions and pressures. Our interest in this study has been not primarily in the perceptual problem of autokinesis but rather in the individual differences it reveals, and in the possible correlations between these individual differences and secondary data on personality.

In a recent experimental study Sherif (**17**) has reported autokinetic perception to be socially modifiable. He also quotes Lewin (**15**) as speaking of a frame of reference for anchorage—Verankerung—in a social situation, and himself further suggests that the individual produces a subjective frame of reference in a dark room situation as afforded by the autokinetic experiment which, expressed in norms, holds relatively true for a given individual upon retest. Sherif thinks this frame of reference to be different in a social situation from that in which the individual is alone

Aside from differences in social reactions, persons are known to differ in their cognitive processes as demonstrated by the Rorschach tests and by the many aberrational experiences in clinical cases. Benedek and Angyal (**4**) have recently pointed out the close relationship between conceptual and perceptual content, particularly as relates to the optic field, and the importance attached to a proper integration of these functions with objective reality. Lewin (**14**) and Brown (**5, 6**) have postulated that personality is characterized, among other things, by a differentiation of the reality dimension of the psychological field. In a perceptual cognitional sense this dimension has its greatest reality value at the level of objective perception and then ranges to other levels to which, in the extreme, the experiences of phantasy or dreaming might be ordered. Brown (**5**) has ventured the further assumption that individuals may differ in respect to these

reality differentials. Since the autokinetic phenomenon is subjective in nature and presents characteristics which might be viewed as representing varying degrees of adherence or anchorage to objective reality, we have advanced the assumption that this phenomenon may be related to the Lewin and Brown concepts of personality structure and to such responses as are found in the Rorschach tests.

In a preliminary study (**21**) we compared various autokinetic measures with Rorschach findings, specifically with Erlebnistypen, and with results obtained by Shuey (**19**) who used Rorschach tests supplemented by other measures obtained from handwriting, tapping tests, Pignet index, personal history, etc. On the basis of gross positive correlations found in this preliminary work, and on the further ground of a general internal consistency of the autokinetic test itself, our present study was conducted. The paper here presented is the first in a series to investigate some personality factors in autokinetic movement, and contains only the findings on normal subjects. Ensuing papers will deal with data on psychiatric subjects and with more extended theory. At present approximately seven hundred patients at the Topeka State Hospital have been given autokinetic tests and comparisons made between the results of these tests and major clinical syndromes. In conjunction with this about one hundred patients receiving shock treatment have been studied and will furnish additional material for further reports.

Method

Our tests were performed under several different controlled situations. One group of 149 subjects furnished the main body of tests, each conducted under identical conditions. Twenty-five of these subjects were individually retested at varying intervals but under similar experimental circumstances to determine the reliability of the test. A second series of tests was performed by 121 persons not participating in the first series, for added comparison with the first series, thus making 270 individual test performances. Three hundred and ten university laboratory students were tested in groups of 12 to 15 individuals to ascertain whether group results are sufficiently similar to individual records to warrant group administration of the test, and to see what specific changes, if any, occur in autokinetic perception in a group situation. As a correlate to this, 25 of these students were retested individually. Finally, in order to further differentiate individuals, 19 were supplementarily tested for inhibitory and facilitating ability. These subjects were chosen to cover the entire range from low to high amount of movement, and were members of the group of 149 subjects tested in the first series. This first series was comprised of students, faculty members and others willing to perform the test. The ages ranged from 12 to 70 years. The sexes were divided into 91 males and 58 females. The second series of 121 subjects was obtained from a more general adult population—82 males and 39 females.

Apparatus and Experimental Procedure.—The equipment consisted of a small light-tight box approximately 7″ × 9″ × 7″ containing a bulb of low wattage suitable for 110 volt current. A small aperture was cut in one side of the box which was then covered with a cardboard containing an opening of pin-point size, 1 mm or less. Several thicknesses of red tissue paper were pasted over this opening to reduce the intensity of light. For recording purposes a large graph board was used, 22″ × 28″ in size. Any clear sheet of paper the size of the board served as a recording sheet. Newsprint paper proved convenient. The paper was held in place by small nails protruding from the rim of the board over which was placed a wooden protective frame about 1½″ in width and in all the same size as the graph board.

During the test period, ten minutes in length, the subject sat at a small table about ten or twelve feet from the light and directly facing it. His eyes were to be held fixed on the light and the head as steady as was comfortable. He was told to consider the dot at the center of the board as representing the normal position of the light and the whole chart before him as the total visual field around the light. He was instructed that if during the test period he were to see any movement of the light he should draw a continuous line graph of this movement as accurately as possible both as to direction and speed, starting at the center where he was to hold his pencil in readiness. All complete stops the light might appear to make from time to time should be indicated by a heavy dot. Intentional returns to center were to be made only in case the movement finally led out of bounds. Such returns were to be made by raising the pencil back to a guessed center. As long as no movement could be observed position was to be held at the center starting point. During the test period the subject was left alone in the dark room. Care was taken as much as possible to avoid giving the subject any impression as to the exact significance of the experiment, or to place any premium on seeing or not seeing movement. These ten minute periods provided the standard for all test performances except those done in inhibition and facilitation. Exact procedure employed in these tests will be described in the section on supplementary tests. Occasionally extra test sessions were held with certain individuals to gain further introspective data, to attempt production of movement where none was observed in the first test, and to determine the subject's ability at voluntary directional control of movement (such voluntary control was markedly present in some subjects).

Determination of Measurements from Qualitative and Quantitative Characteristics of Graphs.—Aside from the relatively few cases (about 14 percent) where no recordable autokinetic movement was experienced, the patterns and extent of movement were, in a strict sense, as varied as the number of subjects tested. For descriptive purposes, however, some major tendencies in patterns will be pointed out and measurements given which we believe most representative of the various records obtained.

Graph Patterns.—Qualitative or pattern characteristics of graphs might best be described relative to the amount of movement the subject experienced. In general, where only relatively little movement was seen the path seldom progressed far without being interrupted by stops of greater or lesser duration, such movement usually hovering closely around the starting position. In a few cases of this kind the path deviated somewhat more from center but was still amply and uniformly punctuated by stops. Occasionally a subject would report having experienced a long initial delay at center, suddenly then to be broken by an unexpected short straight run of movement, only again to be broken by another long stop, possibly for the remaining duration of the test period. Such sporadic movements sometimes took the form of several runs interrupted by several long stops or short oscillations or small spirals of some duration, and in some subjects became more extensive in scope, that is, the path went farther afield. A very characteristic graph representing more extensive movement showed a pendular-like action, usually of considerable amplitude, with stops occurring more generally at the extremes of the swings. This form of reaction was noted particularly among left-handed subjects, or where a history of handedness reversal or stammering could be elicited. Such graphs often covered one-third or more of the length of the board. Another pattern of about this same dimension had what one might call a 'squirmy' or vermicular appearance. Sometimes the path was less pronouncedly vermiculated but still showed many abrupt changes of direction, occasionally with small uniform oscillations of a rather characteristic manner. In most of the graphs of medium expanse stops tended to be less uniformly distributed. Finally there were graphs in which the movement took the form of long uninterrupted sweeps, not infrequently running out of bounds of the board. Here stops were, as a rule, less frequent and shorter. From subsequent tests and personal inquiry it was learned that subjects who were able to experience such extensive movement were also often quite apt in voluntarily controlling its direction. Such control was found less frequently among individuals showing less extensive movement, practically never occurring in those showing only small amounts. We believe pattern differences have some significance in personality structure, as will later be pointed out.

Quantitative Measurements.—In seeking for a measurable criterion for designating personal differences in autokinesis, the first to suggest itself was to use only the total length of path of movement. It seemed quite obvious, however, that stops were also important. One might say that an individual who experiences stop upon stop in the course of movement is more like the individual who sees no movement whatever, and displays a subjective structure different from one who experiences long uninterrupted passages of movement. The added knowledge that the

latter is also often capable of controlling the direction of motion gives additional support to this notion. Furthermore, in considering objective measures, graph patterns came into consideration, since they varied somewhat according to the amount of movement and distribution of stops. Between the extremes of very little and much extended movement were graphs often displaying erratic characteristics with many fluctuations and changes of direction, often not drifting so far from center but at times having a path of considerable length. Judged by the length of path alone, or even by the length of path divided by stops, these medium or erratic graphs could not always be distinguished sufficiently from those showing extensive unwavering sweeps of motion. By considering, however, excursions from center position, and the expanse of the graph as a whole this difficulty was eliminated. In our preliminary comparisons of autokinetic findings with Rorschach types the most significant differences were found to exist between the extratensive and introversive cases. These differences were not only in terms of length of path of movement but also in the number of stops, maximum expanse of the graph, and maximum excursion of the movement from center, the extratensive individuals showing, on the average, lower linear values but greater number of stops. From these trends the rule suggested itself that in the treatment of individual differences the total number of stops occurring in a given graph should be viewed as a reciprocal expression, not only of the length of path, but also of the distance attained from center and the expanse of the graph.

In order to bring these various aspects of a graph into a convenient form of expression an index figure was calculated for each test record. These indices provide the basis in this paper for designating individual differences, although the method of obtaining them must be considered as derived from a more or less arbitrary interpretation of graph patterns. The formula used for calculating indices was: $\sqrt{\frac{L \times DC \times ME}{(S+1)}}$ in which L = the total length of path of movement; DC = maximum distance attained from center; ME = maximum expanse of the graph, that is, the distance between the two points farthest apart in the graph; and S = the number of stops. All linear measures were in centimeters. The integer, 1, was added to S to exclude the possibility of a zero quotient in case no stops were noted. The L, DC, and ME measures were multiplied rather than summed to provide greater sensitivity for reflecting individual differences, particularly in retests. Multiplication, however, produced rather large numbers where higher linear figures were concerned, making them somewhat unwieldy for graphing and tabulation purposes. The roots were hence taken to give us indices which brought high numbers within convenient graphing range without excessively clustering low numbers at the positive end. Where movement was so extensive that return to center was necessary the ME measures were taken from the two points farthest apart on the chart, and not as though the movement had extended beyond the boundary of the board. Retests showed high reliability as will be reported in a following section.

Results

Distribution of Cases

In situations where only chance factors are presumed to operate, distribution of measures ordinarily assumes a normal probability curve. Autokinetic cases did not follow this order. Figures 2 to 7 show histograms of the various measures of the 149 cases tested individually. Figure 1 represents the distribution of all individual tests (both series, 149, and 121 cases). It will be seen that particularly Figs. 1, 2, 3, 4, 6, and 7 approach in appearance the form of a J-curve similar to those found by Allport (**2**) in his investigation of various kinds of conforming human activities. Any statistical treatment of data in our investigation must be viewed in the light of this form of distribution. Table I shows the statistical summary of the main series of individual tests (149 cases) represented in Fig. 2. From our findings it is not certain that our measures express exact

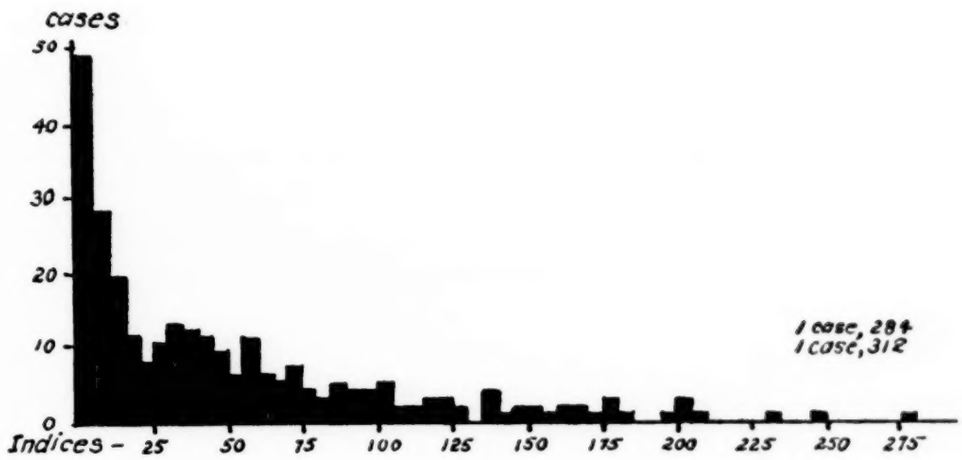

FIG. 1. Distribution of indices of 270 cases (first series, 149 cases plus second series, 121 cases) tested individually. Compare with Fig. 2.

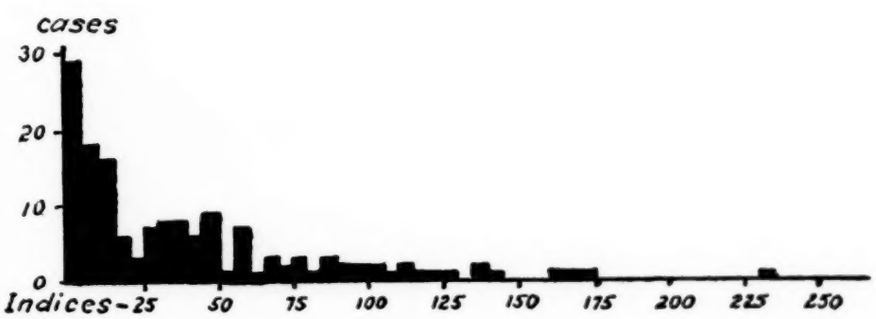

FIG. 2. Distribution of indices of 149 cases (first series) tested individually.

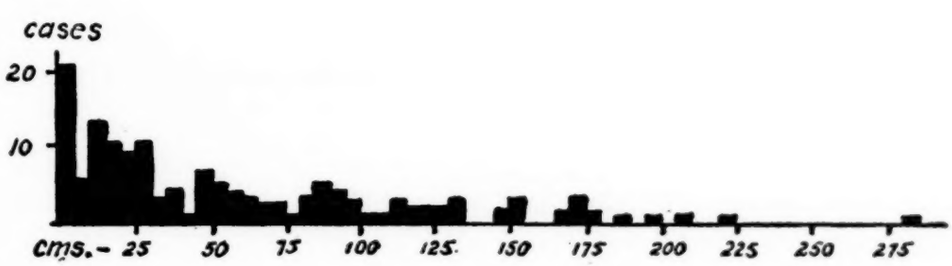

FIG. 3. Distribution of L (total length of path) measures of 149 cases tested individually.

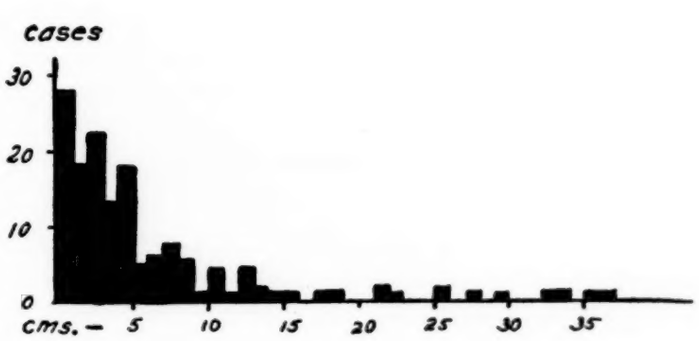

FIG. 4. Distribution of L/S (length of path/stops) measures of 149 cases tested individually.

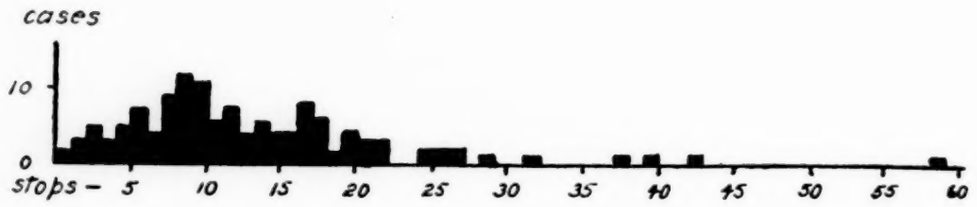

FIG. 5. Distribution of *S* (stops) in 149 cases tested individually.

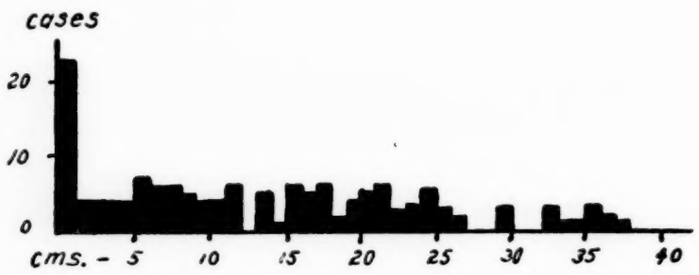

FIG. 6. Distribution of *DC* (maximum distance from center) measures of 149 cases tested individually.

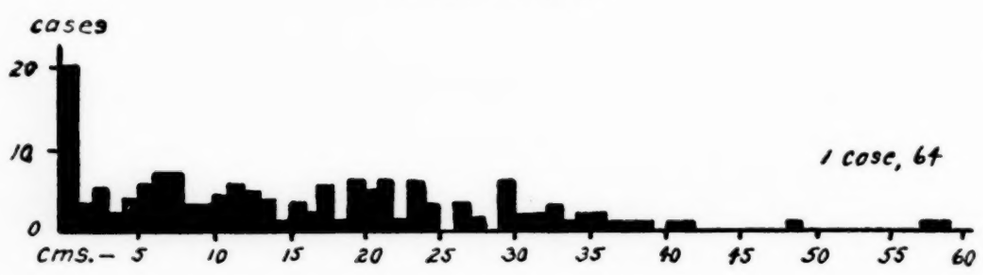

FIG. 7. Distribution of *ME* (maximum expanse) measures of 149 cases tested individually.

TABLE I

SHOWING AVERAGE (AV.); STANDARD DEVIATION (S.D.); STANDARD ERROR OF THE AVERAGE (S.AV.); AND COEFFICIENT OF VARIABILITY (V.); OF THE DETAILED MEASURES OF THE MAIN (FIRST) SERIES OF INDIVIDUAL TESTS—149 CASES

	Index Number	*L*	*S*	*L/S*	*DC*	*ME*
Av.	37.0	56.5	11.4	5.9	13.7	16.6
S.D.	44.1	51.0	9.8	7.5	10.4	13.9
S.Av.	3.6	4.2	0.8	0.62	0.85	1.14
V.	119.0	90.2	86.0	127.0	76.0	83.7

L = length of path of movement; *S* = number of stops; *L/S* = length of path/stops; *DC* = maximum distance from center; *ME* = maximum expanse of graph.

psychological equivalents from person to person. For this reason differences among individuals will probably have to be thought of in a comparative manner which takes into account mainly mass differences in modes of perception. It may be that the autokinetic phenomenon measures only such part of a personality trait as, when investigated by more refined methods, might fall into a normal probability distribution.

We have attempted no study of differences between males and females. By mere chance we obtained more male than female subjects. In terms of percentages alone females exceeded males by nearly twice in zero indices, and in general distribution seemed to gravitate somewhat more toward lower indices.

According to Allport, J-curves are obtained from distributions of measures of prescribed meaningful social acts along a telic continuum. He says, "In a field of conforming behavior the distribution of degree of conformity upon their appropriate telic continuum is in the form of a curve of positive acceleration." This raises for us the question of the possible significance of the form of distribution found in our investigation. Allport thinks that several major influences are at work to produce a J-curve, namely, conformity producing agencies, personality traits, and chance factors, the latter two tending to decrease the pitch of the curve. Biological needs are fulfilled through conforming agencies, and biological activities he views as the manner in which reactions take place directly to the raw physical environment. The fact that the distribution of our cases assumed a J-curve form leads to the inference that in autokinetic reactions we have a personality expression which is probably determined both by conforming agencies and biological factors. Since the conformity or positive end of our distribution curve represents the region of greatest perceptual anchorage, and since the majority of our cases gravitate toward this region, we may further infer that conforming agencies and biological factors favor orientation toward objective reality. Even in our modern culture conditions may still generally favor adherence to objectives having high reality values. Whether race differences, especially those of widely varying cultures, would reflect themselves in changed forms of distribution of autokinetic measures remains conjectural. Sherif (**17**) has discussed at length the importance of social culture for the manner in which a thing is perceived. On field-theoretical grounds we may expect that the larger portion of any society would be found to display capacities consonant with adherence to the objectives of that particular social order. Such capacities may be expected to show themselves in autokinetic modes of perception as in other respects.

Retests

Good reliability in autokinetic tests can be demonstrated, especially where subjects are tested individually. Tables II and III show the results of first and second tests respectively of the twenty-five subjects who were retested. The correlation figure, +0.96, in Table II refers to indices only since they alone are used to designate

TABLE II

SHOWING DATA FOR RETEST COMPARISONS

Turn to Table III for second test results.

Subject	Index Number	First Test				
		L	*S*	*L/S*	*DC*	*ME*
1	1	8	8	1	1	1
2	3	4	2	2	3	3
3	4	13	28	0.5	7	4
4	5	7	4	1.7	4	4
5	7	12	17	6.7	9	9
6	10	15	12	1.2	9	9
7	11	37	13	3	7	7
8	12	18	18	1	12	12
9	13	33	16	2	9	9
10	23	36	5	7	8	11
11	25	47	14	3.3	14	15
12	32	48	22	2.2	21	24
13	38	49	9	5.4	16	16
14	42	98	9	11	12	15
15	45	90	18	5	16	27
16	51	130	17	7.7	15	24
17	51	109	19	6	21	23
18	57	70	16	4.4	28	28
19	59	33	5	6.6	25	25
20	63	212	36	6	26	26
21	70	86	18	4.8	33	33
22	88	122	8	15.2	19	30
23	108	130	10	13	28	35
24	110	59	4	15	32	32
25	129	165	9	18	24	42
Av.	42.3	65	13.5	5.7	16	18.6
S.D.	36	54	7.8	4.9	9.1	11.26
S.Av.	7.2	10.8	1.56	0.98	1.8	2.25
V.	85	83	58	86	57	60.5

Av. = Average; S.D. = Standard deviation; S.Av. = Standard error of the average; V. = Coefficient of variation. *L* = Total length of path of movement; *S* = Number of stops; *L/S* = Length of path/stops; *DC* = Maximum distance from center; *ME* = Maximum expanse of graph.

Correlation between rank orders of indices of Tables II and III, $p = +0.96$.

individual differences. Since the treatment of personal differences is primarily a matter of determining relative positions in a scale of performance the rank difference method of correlation was used. In the light of our present knowledge the absolute values of indices have no significance. In fact, within certain limits individuals do sometimes fluctuate in the amount of movement and stops observed. The exact factors involved in this reach beyond our investigation—fatigue, external distractions, subjective attitudes, etc. may all contribute to the performance at any given time. It has been our experience that those persons who perceive no movement upon first test nearly always fail to do so on second or third attempt. Cases where no movement was ever perceived have not been included in our retest tables. In cases where movement was seen retests have sometimes shown the

TABLE III

SHOWING DATA FOR RETEST COMPARISONS

Turn to Table II for first test results.

Subject	Index Number	Second Test				
		L	*S*	*L/S*	*DC*	*ME*
1	2	7	6	1	2	2
2	2	2	2	1	2	2
3	3	10	27	0.4	5	6
4	2	3	2	1.5	2	2
5	12	16	17	1	13	13
6	8	14	9	1.5	7	7
7	9	33	11	3	5	6
8	5	7	6	1.1	5	5
9	14	29	14	2	10	10
10	31	35	14	2.5	17	21
11	32	62	38	1.6	25	25
12	37	56	25	2.2	24	26
13	45	54	17	3.2	26	26
14	43	113	8	14	10	15
15	61	230	26	9	10	23
16	46	104	10	10.4	13	17
17	45	118	20	5.9	14	26
18	36	55	13	4.2	18	18
19	97	115	8	14.4	27	27
20	84	238	27	8.8	27	30
21	87	84	14	6	37	37
22	145	153	5	30.6	29	29
23	141	175	6	29	22	36
24	97	52	5	10.4	33	33
25	104	194	16	12	22	43
Av.	47.9	78	13.8	7.1	16.5	20.6
S.D.	42.8	70.7	8.9	8	10.19	12.08
S.Av.	8.5	14.1	1.8	1.6	2	2.4
V.	87	90	64.5	112.7	61.7	58.6

Av. = Average; S.D. = Standard deviation; S.Av. = Standard error of the average; V. = Coefficient of variation. *L* = Total length of path of movement; *S* = Number of stops; *L/S* = Length of path/stops; *DC* = Maximum distance from center; *ME* = Maximum expanse of graph.

second pattern to be markedly like the first one. In other cases second graphs have often approximated closely the first ones in general appearance. Even under attitudes of inhibition and facilitation patterns were not nearly always entirely disrupted. The time intervals between the first and second tests ranged from a few hours to several years.

Group Performance

Sherif's (**17**) findings that autokinetic perception is socially modifiable raised for us the query as to what specific changes an individual in a group might show by our method. As already stated, 310 subjects were given group tests, and twenty five of these were retested individually. The general instructions and length of testing time for

groups were the same as for individual tests with the addition, however, that subjects were requested to make no remarks to each other, to be as quiet as possible, and not to jostle each other during the test period. The seating arrangement was such as to eliminate any obstruction of view among subjects.

The most generalized evidence of a difference between individual tests and group results was found in the distribution of indices of the two respective categories, Fig. 1 and Fig. 8. Both of these histo-

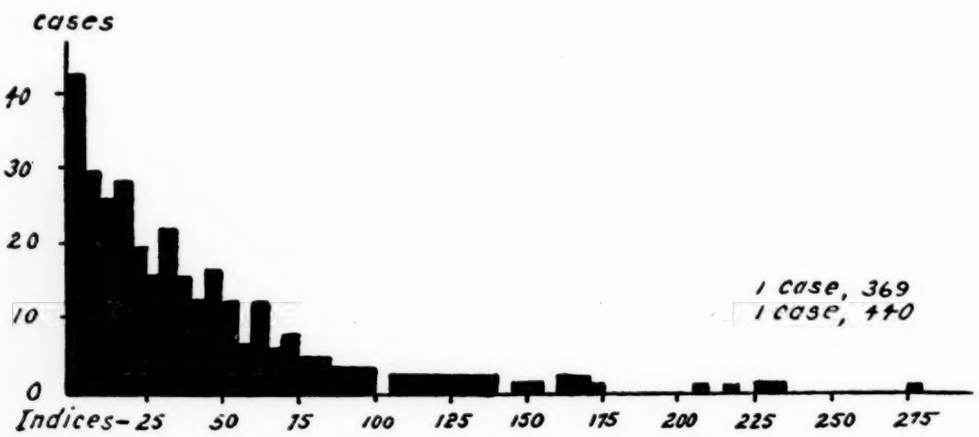

FIG. 8. Distribution of indices of 310 cases tested in groups.

grams have a J-curve form, but whereas Fig. 1, showing individual tests, is somewhat broken in appearance, Fig. 8, representing group tests, presents a smoother general incline toward the positive end. This difference between individual and group results can be viewed somewhat more in detailed repetition in the retest data in Figs. 9 and 10. Retest data showed that in the group situation the most

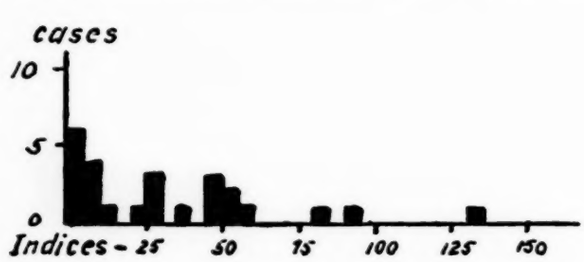

FIG. 9. Distribution of indices of 25 cases retested individually after being tested in groups. Compare with Fig. 10.

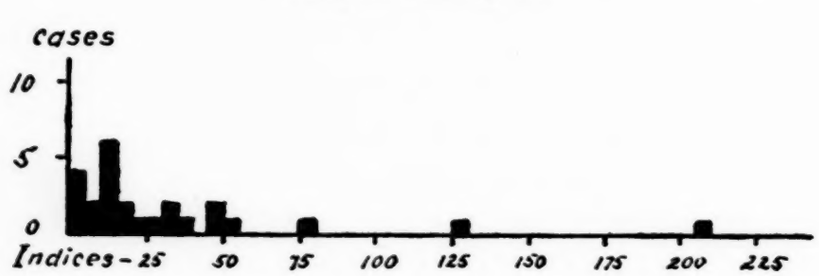

FIG. 10. Distribution of indices of 25 cases tested in groups. Compare with Fig. 9.

noticeable changes in indices occurred in the region of low or medium figures, and that in group the indices proved to be more variable. Stops, on the other hand, were less variable but, on the average, more frequent. In this connection it was also learned that, when in a group, an unusually large number of subjects experienced long stops, many so long that some were wondering whether the light would move again. This tendency to experience long stops was limited in individual tests to comparatively few subjects, mainly to those with low or medium indices, mostly with low indices. An accurate check of the time element in this connection would undoubtedly be necessary in a further study.

A rank difference correlation in the group retests proved to be +0.75. It will be recalled that the correlation figure in retests for individuals alone was +0.96. It is worthy of note that, although in the latter retests the temporal conditions varied considerably from one test to another, they were not sufficient to bring about any great change in the relative positions of indices. In the group retests, however, enough changes occurred to lower correlational results considerably. Just what social factors were involved in bringing about these changes cannot be known from our limited study. A sense of awareness of another's presence may, among other things, be presumed to have its effect. The ease with which a person changes in his autokinetic perception when in a group may throw more light on his personal characteristics, and may aid in further experimental studies in group dynamics. Here again Allport's J-curve hypothesis of conforming behavior suggests that it might be possible to use autokinetic perception as a measure of the degree of group purpose or coherence, or also possibly as a measure of individual antagonism within a group—the confirmed 'nonconformist' might thus be detected. This last point has already received some confirmation from our studies with psychiatric cases.

Supplementary Tests on Inhibition and Facilitation

The procedure in this section was similar to the general test with the modification that the subject was to vary his attitude from time to time. The first two minutes were to be spent in a passive attitude. During the following two minutes he was to make efforts to facilitate movement as much as possible. After this four minutes were to be given to inhibiting the movement. Another two minutes of facilitation followed, and then the final two minutes were spent in passivity. This arrangement of time periods was used to balance any effect practice might have had in the test. With each change of attitude the subject made a mark across the path of movement to indicate the change. Instructions as to attitudes to assume were

given at the proper intervals through the keyhole, usually in simple one-word statements. This was done to avoid unnecessary memory efforts.

The number of cases tested in this section was too small for detailed statistical treatment, hence only averages are given. Finality of conclusion is not offered; nevertheless, a few observations will be pointed out. Reference to Table IV shows that in all three attitudes

TABLE IV

SHOWING MEASURES OBTAINED UNDER VARIOUS ATTITUDES IN THE SUPPLEMENTARY EXPERIMENT

(Each attitude was maintained a total of four minutes.)

Subject	Index Number	Passive Attitude		Attitude of Facilitation		Attitude of Inhibition	
		L	*S*	*L*	*S*	*L*	*S*
Low Indices							
1	2	2	1	1.5	1	1	1
2	5	8.5	7	9	1	5	13
3	6	6.5	5	9	4	1	3
4	7	2	6	3	9	4	16
5	9	20	0	30	7	2	5
6	11	15	6	12	1	6.5	9
7	14	13.5	3	11.5	5	7	4
Av.	7.7	9.7	4	11	4	3.8	7.3
Average *L/S*	—	2.5		2.7		0.52	
Medium Indices							
8	25	8	7	9	4	10	6
9	32	26	11	25	6	5	7
10	42	31	4	44.5	3	26.5	1
11	45	15	7	32.5	7	5.5	3
12	46	127	0	162	0	26	7
13	49	41	7	64	3	10	20
14	51	23	9	75	6	17	15
Av.	41.7	40	6.4	59	4	14.3	8.4
Average *L/S*	—	6.2		14.8		1.7	
High Indices							
15	88	41	1	47	3	37.5	0
16	100	94	4	101	7	32	16
17	107	26	4	51	3	18.5	6
18	111	48	1	50.5	5	10	1
19	115	69	0	96	0	113	0
Av.	104	55.6	2	69	3.6	42	4.6
Average *L/S*	—	27.8		19.1		9.1	

Av. = Average. *L* = Length of path. *S* = Number of stops. Average *L/S* = Average length of path/average number of stops.

the average length of path increases progressively from low to high indices. A summary comparison of these averages from attitude to attitude, using passivity as a basis for comparison, shows the tendency of those with low indices to facilitate poorly but inhibit readily; for the middle group to be capable of both facilitation and inhibition, while persons with higher indices inhibit less readily and facilitate only moderately well. The L/S measures tend to bear out this summary. Inability readily to facilitate is not necessarily synonymous with inability voluntarily to control direction of movement. From information gained from various subjects facilitation seemed best possible when they assumed a quiescent mood or 'lost' themselves in the experimental situation. It is conceivable that in these controlled experimental sessions subjects put forth effort to facilitate, which can be viewed as psychologically different from 'losing one's self.' One may conjecture that some individuals possess, more than others, a certain resiliency of attitude or fluctuation of mood which lends itself more readily to the particular experimental situation here involved.

Psychological Reactions and Introspective Data

The manner in which psychological tensions are discharged or reacted to furnishes important clues to personality differences. It can be assumed that the situation necessary for the autokinetic test offers a certain psychological barrier, or establishes tensions of one sort or another which the subject attempts to resolve. It was, for instance, not uncommon for a subject who saw little or no movement to state that "it got on his nerves" to sit there for ten minutes to watch the light, or that it would make him 'jittery' if he had to continue that kind of an experiment very long. Persons capable of seeing extensive movement often spoke of a delightful feeling or absorbing interest accompanying the observation of motion. Individuals who saw little or no movement often came out of the experimental room in an unenthusiastic frame of mind—for them nothing particularly exciting or noteworthy had happened. Even they, however, had not been entirely perceptually static. It was quite common for them to report having seen the light change size, shape, or color. Often halos were seen around the light or rays emanating from it. Changes of size sometimes had the perceptual effect of movement toward or away from the observer.

Several subjects with rather high indices volunteered the observation that while the movement was occurring the light appeared mainly as a disc on a dark field. Whenever the light gave off rays and appeared to be an object within a structurized space movement tended

to stop for brief moments. This realizing, structurizing activity which some individuals seem more capable of performing over a protracted period of time is undoubtedly brought into play when inhibition is attempted. It seems that persons who were able to visualize, or 'feel,' or sense the pattern of the experimental room were also better able to hold the light in a stationary position. As an example, one subject, with zero index, when asked whether she had seen anything else in the room during the test beside the light, answered affirmatively, naming several objects. When asked whether she had really visibly seen them she hesitatingly said, 'no,' but then emphatically added, "I knew they were there." Such a sense of orientation and general sensitivity to all kinds of extraneous things and occurrences seemed more characteristic of subjects with zero or low indices. Those with relatively high indices seldom reported being disturbed by, or aware of, outside occurrences. They seemed less overt and readily preoccupied themselves with the movement of the light. For them there was quite patently greater economy in the perception of movement. Their introspective accounts seemed to show that autokinetic movement sometimes served as a reflection of thought content—several gave rather detailed description of how the movement appropriately synchronized with directional trends in mental imagery. These individuals were usually capable of voluntary directional control of movement. Repeated efforts were made to induce movement in subjects with zero or low indices through suggestion, but this was practically without success. At the end of such sessions such subjects would usually make some remark, like, 'not much luck,' or, "it just can't be done." Beyond color changes, ray emanations, or slight egocentric movement, their orientation seemed fixed.

Some Theoretical Implications for Further Research

In our treatment of personality differences we have not attempted clarification of any of the terms commonly applied to personality types such as 'extroversion-introversion,' 'syntonic-distonic,' etc., but rather have undertaken an investigation of the individual's differentiation as to psychological reality. It may be that some of our findings are related to the problem of extroversion and introversion. The behavior generally observed in so-called extroverts can be more readily ordered to a field of high reality having the objective situation in mind. In this sense one could think of the perceptual behavior of persons who see little or no autokinetic movement as extroversive in that they do adhere to the situation before them as it objectively exists. The introvert with his world of his own making, on the other hand, shows characteristics similar, in a general sense, to the per-

ceptual behavior of persons who create visual autokinetic patterns of their own liking out of a given objective stituation. That individuals might carry over into other activities the characteristics shown in autokinesis is only an inference. However, our work now in progress among psychotic patients thus far tends to strengthen this idea. From some charts in which autokinetic indices, listed progressively from zero to the highest number, were compared with various graph patterns, and also partly with Rorschach results, we found that certain grossly defined points on the charts appeared to differentiate the whole array of cases into group characteristics. These points, more or less arbitrarily chosen, proved to be at indices 20 and 65, giving thus a tripartite division of all the cases. Some such division might have its value in further typological studies of personality.

The findings among stammerers and individuals with left-hand components are here offered for further consideration. It will be recalled that such individuals produced predominantly pendular-like graphs. The fact that these graphs so frequently showed oscillatory or pendular-like swings may give some clue for the problems of stammering and kindred erratic manifestations.

The reactions of children are mainly unknown to us. We have had only a few cases but have found them to see movement quite early, the youngest being age 6. Two were tested at age 12 and then again at age 17. Here second test results were markedly similar to the first test, indicating a rather early establishment of autokinetic propensities.

Inasmuch as the distributions of our cases point to some social implications it may not be amiss to suggest that with varied social or economic strata of a given society divergencies in distribution characteristics might be found. Well established occupational or professional groups, or bodies of people with special intellectual interests might be found to show some distinct differences as total units. Conversely, such group determinations might then be an aid for further clarification of some of the personality traits or characteristics of the constituents of these various bodies of society.

Summary

In this paper a report has been made of the autokinetic reactions of approximately six hundred persons, some having been tested individually, some in groups, and about fifty were given retests for reliability determinations. The autokinetic phenomenon constitutes the subjective experience of movement of a single pin-point stationary light in an otherwise totally dark field. It has been shown that wide variations exist among individuals in the amount and form of this illusional experience. On the basis of some theoretical considerations

regarding the reality dimension of personality, and through preliminary correlational studies with established personality tests, personality differences have been suggested as expressed through various forms and amount of autokinetic perception. Index figures have been determined to delineate these personality differences. Statistical tables and histograms have been included to clarify obtained measures. Supplementary tests in inhibition and facilitation have furnished additional differential data. Group results have been treated separately from individual test results, and a few implications pointed out for a possible study of group dynamics. Psychological and introspective data have been reported to aid in further understanding of the personal traits of individuals with differing autokinetic responses. In conclusion some theoretical implications are offered for further research.

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THE WEBER–FECHNER LAW AND THE DISCRIMINATION OF COLOR MASS

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The problem of the interrelationships of various psycho-physical methods is an intriguing one. Among questions for which answers have been sought is whether the application of two or more experimental or mathematical treatments (methods and processes in Thomson's terminology (1)), to psycho-physical variables yields congruent results. Not all possible intercomparisons have been made, and frequently only certain phases of the main problem have been dealt with. Thus Thurstone (2) investigated the validity of the Fechner law in the discrimination of dot density, using the method of equal appearing intervals. To find the regression of the S values on R he determined the median S values for each of 24 stimulus magnitudes and plotted them against log R (the logarithm of the number of dots on every card). According to the Fechner law the plot should be linear. He decided that the deviations of the experimental values from the calculated linear values were so slight as to justify the conclusion that the law had been verified. Urban (3) reworked Thurstone's results, using an adaptation of the method of constant stimuli, and found that Weber's law was rather poorly satisfied by the data, but that a surprisingly good verification of Fechner's law was obtained, provided that the latter law were modified to read: If a stimulus interval is divided into a number of steps, which the subject perceives as equal, the estimation values of consecutive steps are in constant ratio. Thus for the material chosen the Fechner law was verified by both methods. No attempt was made, however, to determine whether they yielded the same relationship between S and R values. In this paper the methods of these authors are adapted to another psycho-physical procedure, that of ranking, to determine the discrimination of color mass, and the findings from both methods are compared.

Thurstone and Urban applied their techniques to data which, though gathered in a group experiment, were excellent as a basis for discussion. The data here presented are taken from a previous paper of the author's and were also gathered in a group experiment. The material and method have been described at some length and need not be repeated. Table 1 which has been extracted from those papers is a composite frequency table, summarizing 57,600 judgments. It differs from Thurstone's Table 1, chiefly in its greater precision and the greater number of its equality judgments—12 of

TABLE 1

FREQUENCY DISTRIBUTION OF STIMULI TO VARIOUS SERIAL POSITIONS FOR ALL SIX COLOR COMBINATIONS (N = 57,600)

Stimuli	23	22	21	20	19	18	18	19	20	21	22	23
23	3903	449	195	146	76	19	9	1		1		1
22	435	2931	706	455	177	55	20	13	3	1	4	
21	210	714	2503	838	343	100	49	22	10	6	3	2
20	106	373	808	2532	614	198	95	40	11	13	7	3
19	67	191	368	506	2850	494	150	111	21	21	17	4
18	53	92	133	209	463	3021	544	143	55	38	36	13
18	9	25	46	59	118	561	2990	554	200	123	79	36
19	8	11	20	29	93	201	519	2880	472	310	194	63
20	3	6	12	13	27	83	220	601	2484	823	437	91
21	2	2	6	9	24	43	101	251	880	2558	714	210
22	2	4	3	3	9	20	72	138	500	690	2867	492
23	2	2		1	6	5	31	46	164	216	442	3885

the 141 judgments are greater than ½, as compared with 3 on 169 in Thurstone's table. The greater precision of the present data may be due to the fact that Ss had more extensive practice. Each of the 32 Ss took 25 trials with 6 different color sets; thus there were 4800 rankings for every stimulus magnitude. Thurstone allowed 4 repetitions of the stimulus magnitude to each of his 101 Ss, so that there were 404 sortings for every stimulus magnitude.

The median S values were determined as in Thurstone's procedure, and are listed in Table 2, along with the values of log R. When S is

TABLE 2

Number of Dots R	S_e	log R	k. log R	Median S-value S_e
23	22.884	1.36173	60.464	22.761
22	21.828	1.34242	59.606	21.903
21	20.912	1.32222	58.709	21.006
20	20.061	1.30103	57.768	20.065
19	19.059	1.27875	56.779	19.076
18	18.096	1.25527	55.736	18.033
18	18.109	1.25527	55.736	18.033
19	19.028	1.27875	56.779	19.076
20	20.081	1.30103	57.768	20.065
21	20.926	1.32222	58.709	21.006
22	21.831	1.34242	59.606	21.903
23	22.882	1.36173	60.464	22.761

plotted against log R as indicated by the equation $S = K \log R + K \log C$, and the constants of the line are determined by the method of least squares, the equation of the curve is $S = 44.042 \log R - 37.703$. Figure 1 shows this curve in the exponential form $R = 7.084e^{0.0519S}$. It is to be noted that the number of dots of the predominating color on six cards of every set corresponds to the numbers on the six cards of the predominating color forming the other

half of the set. As a consequence there are six R values, and two S values for every R. The experimentally found S values corresponding to every R differ but slightly, and the same line may be fitted to them. The constants for the lines fitted by the method of least squares was determined for each half of the set of cards (*i.e.*, for the six stimuli of the same predominating color). They are respectively

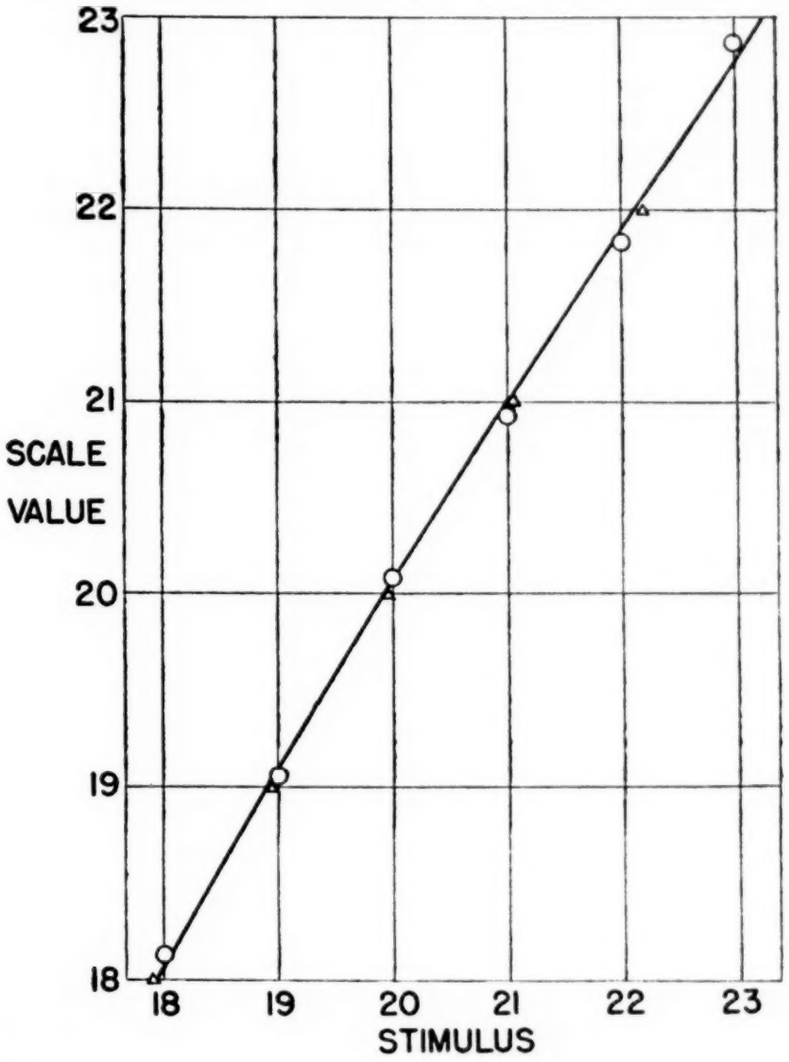

FIG. 1. Relationship between S (scale values) and R (stimulus magnitude). The fitted curve is $R = 7.084\, e^{0.0519S}$. Scale values obtained by Urban's method are represented by small circles: scale values obtained by Urban's method are represented by small triangles.

$S = 44.387 \log R - 37.684$ and $S = 44.418 \log R - 37.722$. It is seen that the average of the constants from each half of the set yields the same values as a determination of the constants from all the values. The maximum difference between experimental and calculated values occurs for $S = 22.884$ and is 0.123, while the average difference between all such values is 0.066. Hence the experimental deviations from Fechner's law are so very slight as to justify us in concluding that the law is verified in this instance.

Urban has shown that the data of Table 1 may be treated by an adaptation of the method of constant stimuli, by resolving that table into a number of tables with the categories 'smaller,' 'equal,' 'greater' giving the frequencies of these judgments for each of the standards. His method is based on the following scheme:

> The relative frequency of the 'greater' judgments for the standard i and the relative frequency of the 'smaller' judgments for the standard $i + 1$ add up to unity. The values of γ are equal in both sets of equations and corresponding equations have the same weight. The observation equations for the constant, of the psychometric functions of the 'greater' judgments for the standard i are identical for those for the constants of the psychometric functions of the 'smaller' judgments for the standard $i + 1$. The following proposition holds true for every standard. The constants of the psychometric functions of the 'greater' judgments are equal for those of the psychometric functions of the 'smaller' judgments for the next higher standard. It is sufficient to do the work for the 'greater' judgments in order to obtain the complete adjustment of the data in Table 4.

TABLE 3

Standard	S.D.$_e$	S_2	S_1	$S_2 - S_1$	E
23	1.766	—	22.848	—	—
22	1.812	22.848	21.594	1.253	22.221
21	1.732	21.594	20.474	1.120	21.034
20	1.585	20.474	19.465	1.009	19.969
19	1.523	19.465	18.456	1.009	18.960
18	1.484	18.456	17.500	0.956	17.978
18	1.544	17.500	18.488	0.988	17.994
19	1.615	18.488	19.436	0.948	18.962
20	1.796	19.436	20.477	1.041	19.957
21	1.676	20.477	21.545	1.068	21.011
22	1.468	21.545	22.654	1.108	22.099
23	—	22.654	—	—	—

TABLE 4

THE POINT OF SUBJECTIVE EQUALITY AND RELATIVE THRESHOLDS

Standard	$E_i : E_{i-1}$	$\frac{S_2 - S_1}{E}$
23	—	—
22	—	0.0564
21	1.056	0.0533
20	1.053	0.0506
19	1.053	0.0532
18	1.055	0.0532
18	1.054	0.0549
19	1.053	0.0500
20	1.053	0.0522
21	1.052	0.0508
22	—	0.0502
23	—	—

A table similar to Urban's Table 4 was drawn up but is not given here. It is merely a cumulative frequency table given in percentages, for every row of the original frequency Table 1.

Urban further states:

> There are no data for determining the lower limit of the interval of uncertainty for standard 1, and the upper limit for standard 10 (*The end standards*). The interval of uncertainty for

standard i is defined as the interval of the stimuli, in which the 'smaller' judgments as well as the 'greater' judgments have probabilities not exceeding ½. Outside of this interval the probabilities either of the 'smaller' judgments or of the 'greater' judgments exceed the value ½. The length of this interval gives an indication as to the precision with which the standard i is perceived. The interval of uncertainty plays the same part in these experiments as in ordinary psycho-physical work.

Urban comments on the labor involved in setting up the observation equations. Tables of Muller-Urban weights and products are not of much help for the percentage cumulative frequencies in this study were calculated to four places of decimals, owing to the number of judgments and the fineness of the tail distributions. In addition the stimuli were carried to a greater range than is given in the Muller-Urban tables. As a consequence the values of w and j had to be calculated from the Kelley-Wood tables (**5**);—j being given under the heading x of that table, and w from the product of z/p and z/p and the constant factor 1.5708. Intermediary values were found by interpolation. Values smaller than $q = 0.001$, at the extreme tails of the distribution, were approximated from an extrapolation curve, a procedure which gave sufficient precision, owing to the small weight of those extreme values. The values wj, ws, ws^2 and wsj were obtained by using logarithms, and the products were checked on a calculating machine.[1]

Since the intervals of uncertainty were obtained from the 'greater' and the 'smaller' judgments, it was imperative that both judgments be carried to the same degree of precision. This could only be obtained by deriving the observation equations from all the stimuli, including the extreme values at the tails of the distribution. The solutions of the normal equations gave the results that are listed in Table 3, which corresponds to Urban's Table 5, except that his h values are replaced by S.D. values. Table 3 furnishes us with material for discussing the Weber-Fechner law.

TABLE 5

Standard	E_c	E_o	S.D.$_c$	S.D.$_o$
23	—	22.884	1.766	0.888
22	22.221	21.828	1.812	1.056
21	21.034	20.912	1.732	1.082
20	19.969	20.061	1.585	1.131
19	18.960	19.059	1.523	1.152
18	17.978	18.096	1.484	1.151
18	17.994	18.109	1.544	1.095
19	18.962	19.028	1.615	1.157
20	19.957	20.081	1.796	1.123
21	21.011	20.926	1.676	1.064
22	22.099	21.831	1.468	1.138
23	—	22.882	—	0.984

[1] Acknowledgment is made of the help given by Miss Miriam Crowley in calculating and checking some of this material.

Weber's law predicates the constancy of the ratio of the threshold of difference to the standard stimulus. On account of the constant errors Urban refers this statement of Weber's law to the ratio of the interval of uncertainty to the point of subjective equality. These ratios are given in Table 4, which corresponds to Urban's Table 6,

TABLE 6

DECREMENT IN GENERALIZATION GRADIENT

Stimulus	21	20	19	18	18	19	20	21	22
Factor	—	.3414	.3414	.3414	.4635	.4635	.4635	.4635	.4635
Calculated values	5061	1726	589	201	93	43	20	9	4
Experimental values	5061	1718	594	201	92	46	19	12	5
Deviation	—	+8	−5	—	+1	−3	+1	−3	−1

Calculated values are obtained by successively multiplying the first value, 5061, by the factor above every calculated value.

under the heading $\frac{S_2 - S_1}{E}$. Urban puts Fechner's law in a form which reads as follows: The estimation value: *i.e.*, the point of subjective equality increases as the logarithm of the stimulus, from which it is evident that the ratio of equidistant estimation values must be constant. The ratios which test the Fechner law are given in column headed by $E_i : E_{i-1}$ and may be compared with the values of $\frac{S_2 - S_1}{E}$, which test the Weber law.

Urban found in his Table 6 that the values of $\frac{S_2 - S_1}{E}$ yield a 50 percent difference between the largest and the smallest values; while the $E_i : E_i - 1$ values show a corresponding difference of 4 percent. The maximum and minimum values of our data for $\frac{S_2 - S_1}{E}$ are 0.0564 and 0.0500, and, for $E_i : E_i - 1$, 1.0564 and 1.0518, which yield differences of 13 and 0.4 percent respectively. Urban finds the agreement between his $E_i : E_i - 1$ ratios remarkable in view of the lack of precision in the determination of the E values and the complexity of the situation; yet our values have a considerably greater accuracy. Both experiments tend to show the superiority of the agreement of the data with Urban's modification of the Fechner law rather than with the Weber law.

It is of interest to compare the scale values obtained in this paper by both methods. Thurstone determined the median scale values from a frequency table of the rankings for every stimulus, whereas Urban determined them by a modification of the method of constant

stimuli. There seems to exist a considerable discrepancy between the scale values as presented in Table 5 which may be readily explained. Thurstone attempts to answer the question: "What is the median sensation scale value S corresponding to a fixed stimulus value, R?"; while Urban poses to himself the question; "What is the most probable stimulus value R corresponding to a fixed sensation scale value S?" In other terms, Thurstone investigates the regression of S on R, while Urban determines the regression of R on S. In this regard Thurstone says:

> In many experimental problems it is necessary to ascertain which of two regressions is to be used. Whenever the object is prediction one should use the regression 'unknown upon known.' In the present case we are not interested in predicting S-values from known R-values, or vice versa. We are interested in the intrinsic relation between S and R. In such a situation one should minimize experimental discrepancies in the variable which is least accurately measured. In this case there can be no doubt that the S-value is far more inaccurate than the R-value, which is merely the number of dots on the card. Consequently we should adjust the S-values against constant R-values. . . . In a situation in which both variables are measured with equal accuracy, and in which no problem of prediction is involved, one should fit the data by a function intermediate between the two regressions.

Fortunately in the present experiment both S and R are fixed and measurable, and save for constant errors in judgment should be evaluated as equal. Hence the relationships should be the same by either regression, and this is what we find. In Fig. 1 are plotted the points as calculated by both methods. It is seen that a curve of best fit for Thurstone's method applies equally well to the points as determined by Urban's method of constant stimuli. The rectifications of the curves in which the points have been fitted by the method of least squares yield respectively, for Thurstone's method,

$$S = 44.402 \log R - 37.703,$$

and for Urban's method,

$$S = 44.576 \log R - 37.960.$$

The corresponding exponential curves are $R = 7.084\, e^{0.0519S}$ and $R = 7.105\, e^{0.0516S}$. Thus it is apparent, in this experiment at least, that the ranking method as a psycho-physical procedure gives congruent results with the method of constant stimuli.

As the psychometric method assumes a normal frequency distribution in the judgments it is of interest to study the dispersion that a stimulus projects on the S scale as given by the frequency tabulation. Thurstone states that these distributions cannot be normal since the results accumulate at the ends of the table. He offers two explanations; one, the mechanical difficulties of curtailment at the ends of the series (subject often would feel that a much larger series would be helpful and consequently tend to build up the extreme cases), and

second, an adaptation effect caused by familiarity with the experimental stimulus range.

While Urban admits these distortions he points out that 7 of the 25 lines in Thurstone's table are approximately normal in distribution, and states that the asymmetry may be explained by the view that we have to deal with normal distributions cut off at one end. The data here given have considerable skewness. From Table 3 of a previous paper (**6**) it was found that when the Pearsonian formula for skewness $\frac{3(M - Mdn)}{\sigma}$ is used, the skewness values average −0.804 for stimulus 23; pass through zero close to stimulus 20, and become 0.474 for stimulus 18.

With the object of testing the dispersion given by the frequency table the judgments from both halves of the table, which are closely similar, were combined, since the stimuli (the number of dots of the predominating color) are the same on either side, the color alone differing. These combined values were then plotted on arithmetic and logarithmic probability paper. Owing to the skewness of the distributions, the plot on arithmetic probability paper is not linear; on the other hand, neither is the plot on logarithmic probability paper, although the linearity of the plot for stimuli 20 and 21 is satisfactory except for the correct judgments. When however the logarithmic decrement of the judgments on either side the correct value is plotted as in Fig. 2, using the combined values from both sides of the distribution (a procedure which is tantamount to obtaining the gradient of generalization for each stimulus), a fair linear plot is obtained. Thus for example when the number of judgments for stimulus 21 are averaged for both colors of a set, and a logarithmic curve is fitted by successively multiplying 5061, the number of correct judgments for the stimulus, by 0.3414 for the first four values, then continuing the multiplication for successive values by 0.4635, a remarkably close fit is obtained, as is shown in Table 6. It will be noted that the change in gradient from 0.3414 to 0.4635 occurs at stimuli 18, that is, where the predominating color of the stimuli changes. The fit to a straight line is not always so good, and from the figure it can be noted that often there is a slight distortion in the gradient around the central values, *viz.*, stimuli, 20 and 21.

A possible explanation of this interesting effect might be found in the nature of the judgment process, as has been suggested by the author in a previous paper (**6**), where it was stated:

> A general level of reference, a base or standard is established at the extreme stimuli from which all judgments are gauged and all estimates are made. This general level of reference persists as a trace through the whole discriminatory process, though it is subject to continuous modification and readjustment. The traces of the standards by which the stimuli

are appraised are sharpest and clearest at the extremes, and possibly that is why the extremes are selected as the reference level. Here the accuracy and precision of the judgments is much greater than anywhere in the series, and the end stimuli are judged with celerity and confidence. Just as the accuracy curves diminish from the extremes to the centre, so do the reaction times of the judgments and the degree of confidence with which they are made. To the degree with which the stimuli deviate from the end points, or levels of reference, do judgments based upon them lose in accuracy, clearness, speed and confidence. This lack of clarity and precision of the trace is not due to decreasing intensity, for the middle stimuli are stronger (*i.e.*, the predominance of color mass is greater) than those at one end, nor to recency, for all the stimuli are simultaneously present, but to the presence of other conflicting stimuli which have an inhibitory effect due to their serial position which is more detrimental then the inhibitory effect for the end stimuli.

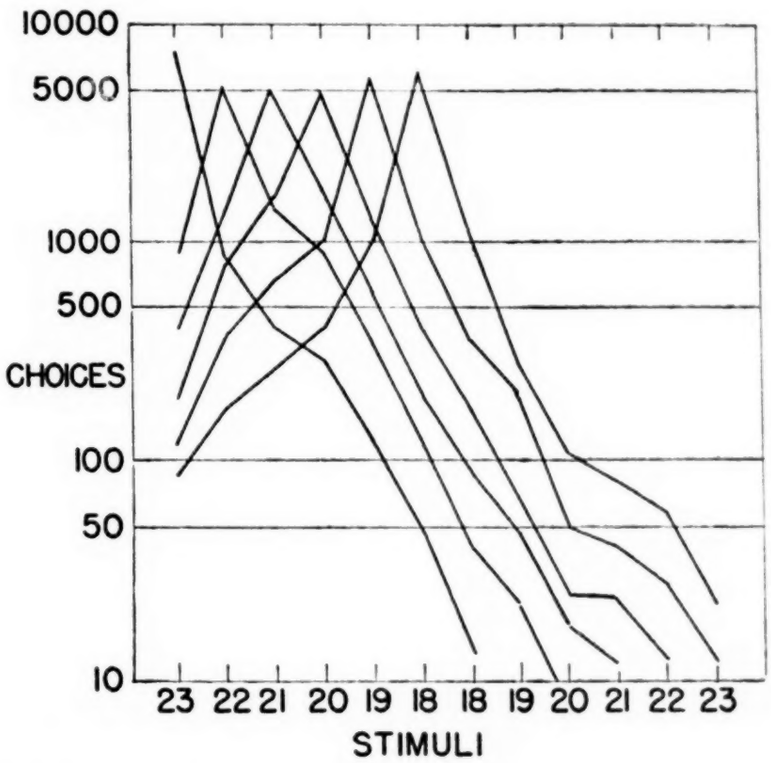

FIG. 2. Gradients of generalization of choices. The plot shown is that of the logarithmic decrement of the choices on either side of the correct value.

In addition to the effect of serial position, the change from one predominating color to another adds a complicating factor in the discrimination, as is evidenced by the change of gradient of generalization at that point. Thus in general the gradients of generalization are approximately constant, but they are often distorted when passing from one color to another, or when they pass through the center of the series, around stimuli 20 and 21, where the traces lose precision.

Additional evidence for this hypothesis may be seen when the total correct judgments for each of the six stimuli are plotted as in Fig. 3. To them is fitted a curve composed of the sum of two exponential curves, the parameters of which have been determined by the method of least squares, according to the method given by

Huntington (7). The equation of this curve is

$$Y = 6338\, e^{-0.4987(23-X)} + 1456\, e^{0.3027(23-X)}.$$

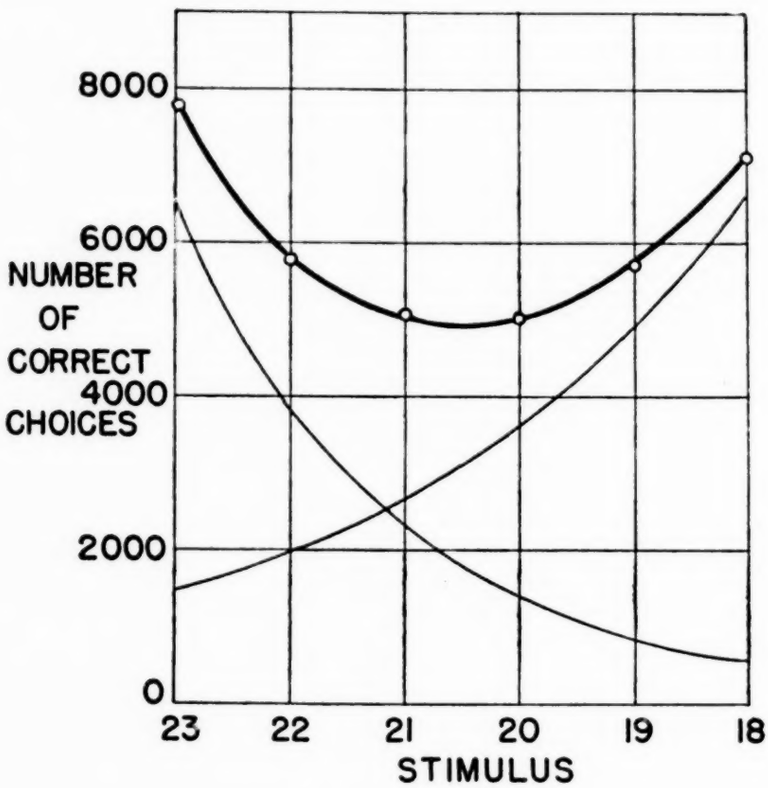

FIG. 3. Number of correct choices at every stimulus position. Experimentally found values are fitted to the equation shown in heavy line $Y = 6338\, e^{-0.4987(23-X)} + 1456\, e^{0.3027(23-X)}$ obtained by summing the ordinates of the two exponential curves given in light lines, which indicate the gradient from each frame of reference at the end stimuli.

The experimental values and the calculated values are given in Table 7. It will be noted that the calculated curve fits the data surprisingly well.

TABLE 7

CORRECT CHOICES FOR EACH STIMULUS POSITION

Stimulus Position	Gradient A	Gradient B	Calculated Values	Experimental Values	Deviation
23	6338	1456	7794	7788	+6
22	3849	1970	5819	5798	+21
21	2337	2667	5004	5061	−57
20	1420	3610	5030	5014	+16
19	862	4886	5748	5730	+18
18	524	6614	7138	7116	+22

The calculated values are obtained from the equation

$$Y = 6338\, e^{-0.4987(23-X)} + 1456\, e^{0.3027(23-X)}.$$

Gradient *A* is the first term of the equation and is the gradient from the frame of reference at Stimulus 23.

Gradient *B* is the second term of the equation and is the gradient from the frame of reference at Stimulus 18.

The equation of the curve is in accord with the hypothesis that the frames of reference for serial discrimination in this experiment are determined from the terminal stimuli, and are slightly clearer at stimulus 23, since the correct values are more numerous there than at stimulus 18, where the discrimination is obscured by the proximity of a different predominating color in the other half of the set.

Summary

1. The validity of Fechner's law is exemplified by data gathered in the discrimination of color mass by the ranking method.

2. Median scale values obtained by Thurstone's method agree closely with scale values determined by Urban's modification of the method of constant stimuli.

3. In this experiment the ranking method gives congruent results as a psycho-physical method with the method of constant stimuli.

4. The distributions of the judgments are considerably skewed, but a logarithmic plot of the gradients of generalization of the discriminatory process is linear.

5. The correct judgments according to serial position fit a curve which is the sum of two exponential curves.

6. Substantiation is thus obtained of the author's theory of serial discrimination based on terminal frames of reference.

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EXPERIMENTAL DATA ON DIFFERENT NEURAL MECHANISMS FOR LEARNED AND UNLEARNED RESPONSES [1]

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I. Introduction

In view of the interest which has lately been aroused by the phenomenon of spinal conditioning (**3, 13**) and the special effects of curare upon the cortical and sub-cortical nerve centers during learning (**4, 6, 7**) it seems advisable to report at this time some previously unpublished data which are related to the study of the neural mechanisms involved in the learning process. The present observations are exclusively behavioral in nature and were obtained from three separate investigations (**1, 2, 8**) no one of which was directed specifically toward the study of neural functions. Each group of observations is by itself somewhat brief, though nevertheless consistent with the others. The object of the present paper is to bring the three together in a single communication relevant only to the point in question.

The first and second of the three studies to be reported have to do with conditioning in stuporous or near-sleeping conditions produced (*a*) by prolonged and continuous periods of training and (*b*) by a depressing drug. The third involves the relationship of the learned and unlearned responses to the side of the body stimulated. The general method employed in all three investigations was the familiar buzz-shock conditioning technique which has been described in detail elsewhere (**9**).

II. Present Observations

Fatigue and Conditioning.—G. B. Brundage (**2**) gave repeated buzz-shock stimulation to several dogs for long periods of time without interruption. In the case of one subject, practice was continued for as long as 52 consecutive hours during which more than 1500 conditioning trials were administered. Other subjects were trained for shorter periods without interruption. The flexion CR was found to develop readily enough by this massed method in from 100 to 300 trials, after which it remained unchanged for many hours. As training continued, however, the CR would sometimes take on a fluctuating

[1] Publication No. 15 from the Indiana Conditioning Laboratory. The research work, upon which this report is based, was made possible by a series of grants-in-aid of research from the University and by continual assistance from the National Youth Administration of the United States Government.

character, and would completely disappear for 30 to 40 stimulations, only to reappear at the end of this interval. Since the respiration of the subject usually changed also at these times we took them to be evidence of the fact that *the subject had fallen asleep.* The neural mechanisms for the CR, whatever they may be, had ceased to function during the sleeping state. Yet the significant fact in this connection was that *the unconditioned response to the shock did not drop out during the intervals when the conditioned response did.* It appeared, therefore, as if the nervous mechanisms for the conditioned response 'went to sleep,' while the nervous mechanisms for the unconditioned reflex 'stayed awake.' [2]

Effects of a Depressing Drug.—Quantitative data related to this problem have been obtained by Headlee (**8**) in the study of the effects of hypnotic doses of pentobarbital sodium upon the flexion conditioning of dogs. Headlee's subjects were injected intraperitoneally with .08 grain per lb. of Nembutal (pentobarbital sodium, Abbott). Prominent among the effects produced by the drug were complete loss of balance and the resulting inability to walk or stand, followed by periods of heavy sleep. While in this state the animals were placed in a conditioning stock—where they were supported by means of a hammock and slings—and were given conditioned-response training throughout a laboratory session of approximately two hours. The unconditioned flexion reflex was arbitrarily maintained at a constant level of 4 in in extent. If the reflex dropped below this magnitude, the experimenter at once increased the intensity of the electrical stimulation. If the extent of movement surpassed the 4-in standard, the intensity of the stimulation was reduced.

Again, in this experiment, the phenomenon of a fluctuating or temporarily disappearing CR was demonstrated, while the UR remained fixed and unvarying—although adjustment of the unconditioned stimulus-intensity was at times necessary.

In Fig. 1 are frequency graphs which demonstrate in a quantitative way the behavior described. They give a record of the percentage of conditioned responses made by one of Headlee's subjects during trials 100 to 199 of the training under the pentobarbital. Although the right-rear member only was shocked, the flexion responses of all four of the limbs were recorded. Any lift or flexion occurring within the 1.8 sec. of buzz (conditioned stimulus) preceding the shock (unconditioned stimulus) was counted as a CR.[3]

[2] An analogous experiment in salivary conditioning has recently been reported by Gantt (**5**). Gantt found that the unconditioned salivary response remained constant for continuous periods of training up to 20 hours in extent, but variations or changes occurred in the conditioned response.

[3] Quadrupedal recording of this sort generally shows the presence of CRs in all the limbs during the early and intermediate stages of training with a dropping out of the responses in the non-shocked members at a later time. *Cf.* Wolf and Kellogg (**14**).

It will be seen from Fig. 1 that CRs in the right-rear member reached a frequency of 40 percent during trials 120–139. In the next 20 trials the subject 'went to sleep' and made no flexions to the buzz with any of the feet. Subsequently he 'woke up,' became generally more active, and responded with a frequency as high as 55 percent in the right-rear (shocked) member during trials 180–199. Yet throughout this disappearance and reappearance of the CR, the unconditioned response was elicited continuously without difficulty.

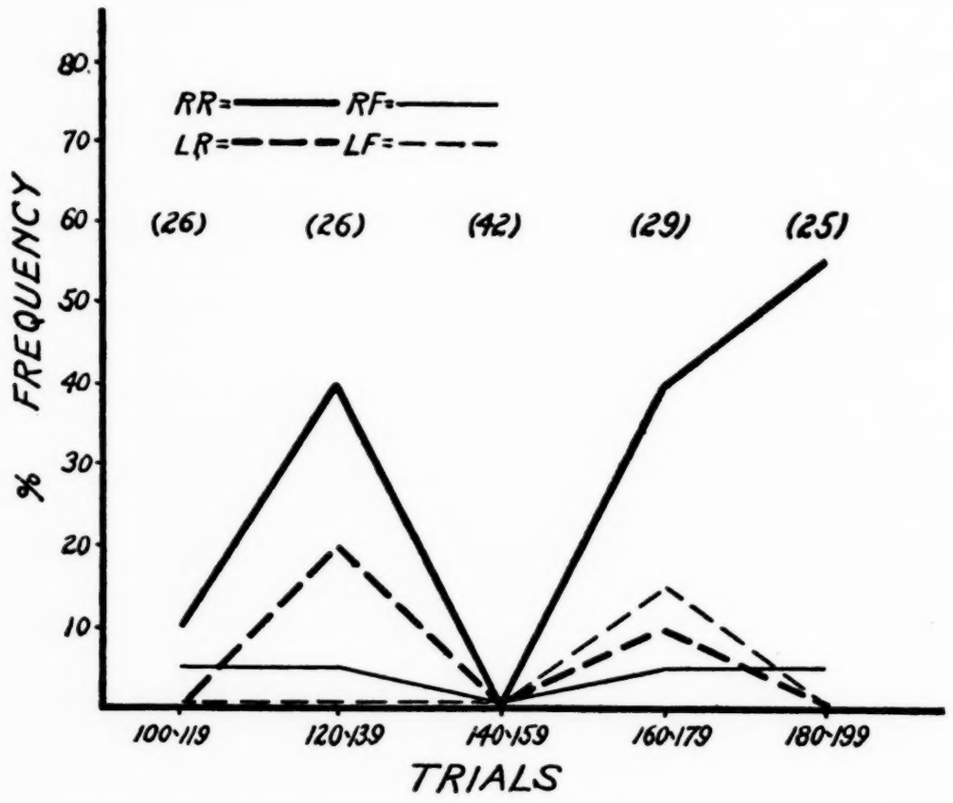

FIG. 1. Showing the relative frequency of CRs occurring in all 4 limbs in a two-hour period of conditioning under pentobarbital sodium. During trials 140–159 the subject 'went to sleep' to the conditioned stimulus, but 'woke up' later. Throughout all of the training, however, a full unconditioned flexion response of 4 in in extent was elicited. The d.c. voltage across the electrodes, which was necessary to maintain the unconditioned response, is given for each group of 20 trials, above the points plotted in the curves.

The number of d.c. volts which were delivered to the electrodes of the right-rear foot are given above the curves in Fig. 1 for each group of 20 trials. From these voltage readings it will be seen that the intensity of electrical stimulation necessary to maintain an unconditioned flexion of 4 in remained fairly constant, except during trials 140–159 when the animal 'was asleep to the buzz.' During these trials *E* had to increase the potential difference across the electrodes from 26 to 42 volts. The intensity of the conditioned buzz-stimulus was held fixed throughout the experiment at 50–55 db above the human threshold.

Perhaps the most obvious way of accounting for the disappearance of one response with the maintenance of the other would be to say that the dog's general level of sensitivity varied under the drug so that the buzz fell below his lower auditory threshold. At the same time the shock was adjusted by the experimenter to remain sufficiently above the tactual threshold to continue to elicit the desired reflex.

An alternate explanation—perhaps unacceptable to some psychologists—would be to account for the phenomenon on a neurological basis. Hence one might say that the cerebral cortex—traditionally the 'locus' of learning ability in the organism—was incapacitated by the drug. But the nerve centers controlling the unconditioned reflex were not so affected.

Laterality and Conditioning.—The possibility of separate neural mechanisms has also been noted by E. G. Brundage (1) who used an altogether different plan of approach to the problem. As part of a study on the relationship between laterality and conditioned behavior, he conditioned dogs alternately, first in the right-rear foot, then in the left-rear, again in the right-rear, and so on until six successive training sequences had been completed. Throughout the experiment he obtained graphic records of both the conditioned and the unconditioned flexion responses in all four of the members.

Although the object of the experiment was primarily to study the responses of the hind feet, the observations which are pertinent to the present communication deal with the lifts of the *front feet* which occurred (*a*) as a result of the buzz stimulus and (*b*) in response to the unconditioned shock delivered to one of the rear feet. When the shock was given to the right-rear foot, the subjects were found to make more unconditioned flexion responses with the diagonally opposite left-front foot than they did with the right-front foot. But during the same training period they made more CRs with the right-front foot than they did with the left-front foot. Similarly, when the left-rear foot was shocked, CRs were more common in the front foot on the left side of the body and URs were more common in the diagonally opposite right-front foot.

These findings may be summed up in the following general statements. *The response to an unconditioned shock in one of the rear feet, is a lifting of the shocked foot combined with a tendency to lift the diagonally opposite front foot. But the effect of the 'diagonal reflex' is not shown in the conditioned response. In the latter case the tendency so far as the front feet are concerned is for the member homolateral to the shocked foot to be most frequently lifted.*

The diagrams in Fig. 2 are designed to clarify and emphasize the nature of these results. The symbols *LF*, *RF*, *LR*, and *RR* in the

figure stand for the left-front, right-front, left-rear, and right-rear feet respectively. The *RR* foot (black circle), in the particular situation illustrated in Fig. 2, is assumed to be the foot to which the un-

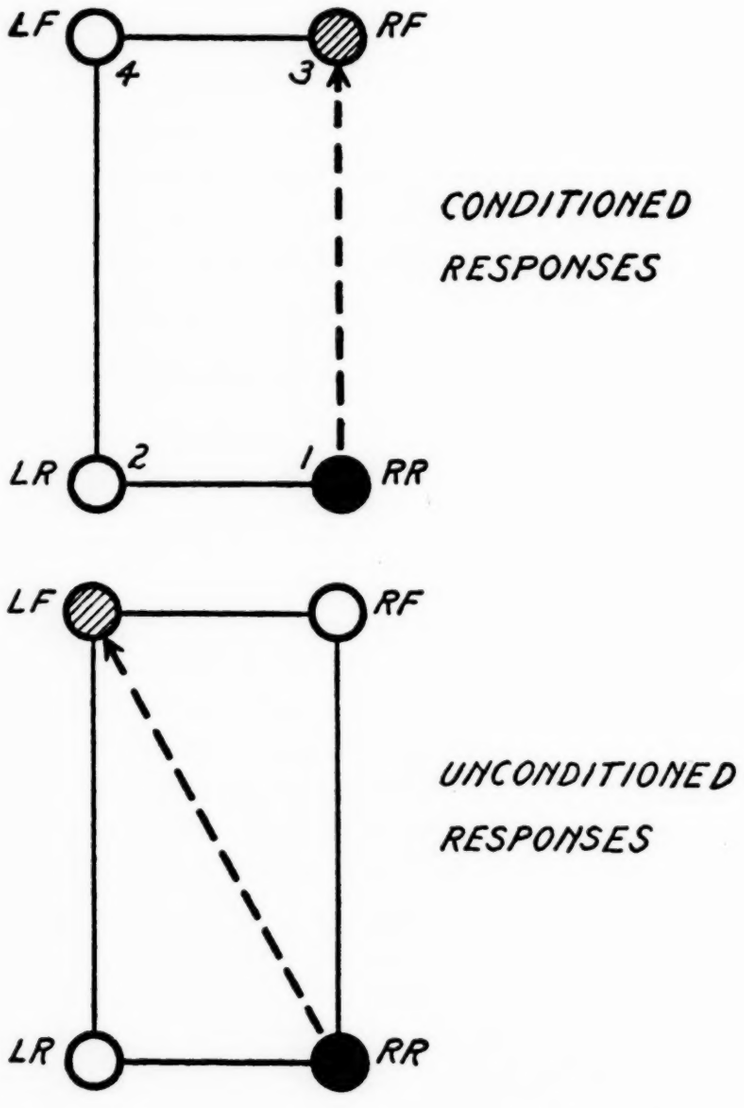

FIG. 2. Showing front-foot response-tendencies during flexion conditioning of the right-rear foot of dogs. In both rectangles, the symbols *LF*, *RF*, *LR*, and *RR* stand for the left-front, right-front, left-rear, and right-rear feet respectively. The *RR* foot (black circle) in this particular illustration is assumed to be the foot to which the unconditioned shock stimulus is delivered. Over a period of considerable training, the different feet will be found to give CRs (responses to buzz) in a frequency order indicated by the numbers in the upper rectangle. As far as the front feet only are concerned, this means that the foot on the same side as the shocked rear member gives the greater number of CRs.

The lower rectangle indicates that the unconditioned responses (responses to shock) made by the front feet are likely to occur more often in the front foot diagonally opposite to the shocked rear member.

conditioned shock stimulus is delivered. Over a period of considerable training the different feet will be found to give CRs (responses to buzz) in a frequency order indicated by the numbers in the upper

rectangle. Thus if the unconditioned stimulus is delivered to the right-rear foot, CRs will be given most frequently by the right-rear member, next most frequently by the left-rear, then most frequently by the right-front member, and least frequently of all by the left-front. As far as the front feet only are concerned, this means that the foot on the same side of the body as the shocked rear member gives the greater number of CRs.[4]

The lower rectangle in Fig. 2 indicates that the unconditioned responses (responses to shock) made by the front feet are likely to occur more often in the front foot diagonally opposite to the shocked rear member. This tendency to raise diagonally opposite feet at the same moment is no doubt a function of the normal locomotion of a four-footed animal. The automatic associated movements required by the trotting gait involve simultaneous timing of diagonally crossed members. In the intact organism such movements are probably under the neural control of the corpus striatum and the red nucleus (**11**). They can also be demonstrated in the spinal preparation as intersegmental spinal reflexes (**12**). It seems reasonable to suppose, therefore, that the diagonal reflex as it has appeared in this experiment is a functional unit of activity which is part of a quadruped's equipment.

Neural Mechanisms and Learned Behavior.—These two divergent patterns of activity observed by E. G. Brundage (**1**), we take to point to the probable existence of different neural mechanisms behind the conditioned (learned) and unconditioned (unlearned) behavior of the organism. They are supplemented by the similar distinctions noted by G. B. Brundage (**2**) when animals were trained during extreme fatigue, and by Headlee (**3**) who conditioned his subjects under the influence of a depressing drug.

But observations such as these need not mean that the neural mechanisms involved are wholly distinct and separate. It seems to the present writer that the mechanisms for the conditioned flexion response very likely include and supplement those of the flexion reflex alone. The mechanisms of the learned act may perhaps encompass the mechanisms of the unlearned, although the mechanisms of the unlearned need not include those of the learned. The two sorts of neural machinery need not necessarily be mutually exclusive. Rather one of them may contain a part or all of the other as a portion of its larger background.

The conditioned flexion response would never develop, for example, without the unconditioned reflex, which furnishes the essential

[4] Kellogg, Scott, Davis, and Wolf (**10**) and Wolf and Kellogg (**14**) have previously reported that the non-shocked feet in flexion conditioning give CRs with a frequency which is proportional to their anatomical distance from the foot which is shocked.

motivation for the task. This fact we take to mean that the lower centers play a part perhaps as fundamental to the conditioning process as do the higher centers. Such an interpretation is opposed to the traditional view that the neural background of learning is essentially 'intra-cerebral.' To 'locate' learning ability in some special region of the organism's neuroanatomy is too much of an oversimplification. The learned behavior of the intact organism, in the case of flexion conditioning, is possibly a function not only of the cerebral cortex, but also of the basal ganglia, portions of the medulla oblongata, the nucleus dorsalis of the spinal cord, and all other relevant nerve centers. It no doubt depends upon an extremely complicated integration between them.

III. Summary

1. Dogs which are subjected to many consecutive hours of massed training by the buzz-shock conditioning method may 'fall asleep' to the conditioned stimulus but 'remain awake' to the unconditioned. After a short rest they will 'wake up' to the conditioned stimulus again.

2. Similarly, animals which are conditioned while under the influence of a depressing drug (Nembutal) may at intervals temporarily lose a well-established CR even though the unconditioned response remains continuously present.

3. A study of the *front-foot* responses made by subjects alternately conditioned in the two *rear* feet shows further that the response to the unconditioned shock in one of the rear feet is a lifting of the shocked foot combined with a tendency to lift the diagonally opposite front foot.

4. But the effect of this 'diagonal reflex' is not shown in the conditioned response. In the latter instance the tendency, so far as the front feet are concerned, is for the member homolateral to the shocked foot to be most frequently lifted.

5. These observations taken as a whole point to the probable existence of different neural mechanisms for learned (conditioned) and unlearned (unconditioned) flexion responses.

6. This need not mean, however, that the two sorts of neural mechanisms are wholly distinct and separate one from the other. It is more likely that the neural mechanisms for the unconditioned reflex are included, either all or in part, in the neural integrations essential for conditioning. If this were not so, the unconditioned reflex would not be necessary as a motivating device for building up the conditioned.

7. Such an interpretation is opposed to the traditional view that the neural centers for learning are 'localized' in the cerebral cortex

or in any other special region of the nervous system. In the intact organism, the neural mechanisms for learned behavior probably involve a complex integration between many different nerve centers, both lower and higher. Among these, the cerebral cortex, of course, plays a very important role.

(Manuscript received April 8, 1941)

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INDIVIDUAL DIFFERENCES IN SIMPLE AUDITORY REACTION TIMES OF HANDS, FEET AND JAWS *

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In spite of the fact that almost every experimental psychologist has at some time done an experiment on simple reaction time, there have been surprisingly few correlational studies to determine the interrelations of various types of reaction times. The present study was initiated by the findings of Reymert (4) which showed that simple auditory reaction times of various musculatures (hands, feet, elbows, shoulder, neck, jaws) were moderately or closely intercorrelated among themselves, but were not related to speed of tapping. From this he concluded that there was a 'personal equation' for simple reaction times, but that this was not the same as the personal equation for serial reaction times.[1] Since his study was based on a small number of cases (13 men, 7 women) which also involved possible sex differences, and included only twenty measurements on each musculature (reliabilities not calculated) it seemed worthwhile to check and extend his type of experiment with larger numbers of subjects and measurements. As the essential findings of the present experiment have subsequently been verified in some respects by other experiments, previously summarized by R. H. Seashore (6), we shall here present only a summary of the setting, observers, instruments and procedures involved.

Fifty men and twenty-five women students in a sophomore laboratory course each acted as observers during portions of a single regular laboratory period. Each person was given fifty trials on simple auditory reaction time of the right hand, followed by fifty more on each of the following musculatures, left hand, right and left feet, and jaws (biting movement). This constituted the first cycle of the measurements, and was followed by a second cycle of fifty trials on each musculature, with rests after every twenty-five trials. With our facilities it was possible to complete the experiment, including instructions and practice trials, in from fifty to sixty-five minutes. The cycle plan of rotating the musculatures to be measured, together with regular brief rests, avoided any large fatigue effects, while the knowledge of results from trial to trial aided the usually high degree of interest or motivation ordinarily found on motor tests.

The auditory stimulus was given by a telegraph sounder having a latent period of approximately .015 seconds and the response was recorded by an electromagnet having a similar latency.

* From the laboratory of the University of Oregon.

[1] Reymert's assumption of a personal equation or group factor covering all serial speeds is found to be far too broad. Buxton (1) and Seashore, Buxton and McCollom (7) have shown a number of very narrow group factors among the many varieties of serial motor tests.

The chronoscope was adjusted to allow for these facts. The newly devised phonograph motor chronoscope[2] was checked both graphically by tuning fork records (Seashore, 5) and during the experiment by the Miles stroboscopic method (3). The readings of the chronoscope were given directly in hundredths of a second, allowing for the latent times of the sounder and electromagnet, so that only the human factors were measured. A simple reset device, operated by the experimenter's left hand, eliminated the necessity for subtracting any initial readings, while a Dalton printing adding machine operated by the experimenter's right hand gave a printed record and total of each set of trials. The mechanism of the machine was silent, thus permitting electrically controlled stimulation (mercury contact) through a single sense field, either visual or auditory. It also had the merit of not affecting the rate of the phonograph motor in any way until after the response had been completed.

Finger movements of approximately 1 mm were made by grasping a small upright post with the hand and pressing the fingers on a specially devised key which was mounted on one side of the post. Foot movements were measured by a slightly larger but similar key placed half way under the edge of the shoe, thus permitting visual check on position. Biting movements of the jaw were measured by a special key consisting of two prongs of thin spring steel[3] separated at one end by a wooden handle and covered for insulation, sanitation, and shock absorbing by removable rubber finger cots. As in the other keys, a movement of approximately 1 mm under light tension was sufficient to record a response.

Observers were instructed to assume a 'motor' set of attending primarily to the response to be made.

The following data for men observers are based upon the averages of all one hundred trials on each musculature unless otherwise indicated, as for the reliability coefficients between cycles 1 and 2 (uncorrected).

QUANTITATIVE RESULTS, SIMPLE REACTION TIMES

	Mean		Sigma (Men)	Reliability (50–50) (50 men)	
	Men	Women		r	p.e.
Right hand	.147	.171	.033	.90	.02
Right foot	.174	.197	.032	.87	.02
Left hand	.144	.168	.028	.90	.02
Left foot	.179	.200	.034	.89	.02
Teeth	.138	.168	.030	.88	.02

SEX DIFFERENCES IN SPEED
(Chances in 1000 of true differences)

	1st 50 Trials	2nd 50 Trials
Right hand	994	981
Right foot	949	953
Left hand	947	981
Left foot	948	960
Teeth	975	999

[2] The first few subjects were measured by a Stoelting electrically operated hundredth second stop watch. Because of numerous hand breakages, this device was soon displaced by the new chronoscope, specially devised for this experiment. The writers are grateful to Miss Arnell Gillett for assistance in recording the early stop watch results. Later work on the new instrument was all handled by S. H. Seashore.

[3] Ford Model T automobile coil points.

INTERCORRELATIONS (100 TRIALS)
(N = 50 men)

	Right Hand	Right Foot	Left Hand	Left Foot
Right hand				
Right foot	.86±.02			
Left hand	.92±.01	.85±.03		
Left foot	.82±.02	.93±.01	.70±.05	
Teeth	.83±.03	.83±.03	.88±.02	.81±.03

CONCLUSIONS

1. For a group of 50 university men (laboratory students), individual differences in speed of simple reaction to an auditory stimulus were found to be quite stable from one cycle of fifty trials to the next cycle, both measured within the same hour. This was shown by coefficients of correlation between the two cycles of from r = .87, p.e. .02 to .90, p.e. .02 for the five musculatures of right hand, right foot, left hand, left foot, and teeth. The stability of the means of 100 trials are, of course, somewhat greater.

2. The term 'personal equation' taken by Reymert from older experiments is probably better described as a 'group factor' of the type found by Seashore, Buxton and McCollom (7). Our results, however, confirm Reymert's (4) essential findings on intercorrelations of individual differences in speed of simple reaction of five musculatures to an auditory stimulus. Intercorrelations were highest between hands or between feet. This is shown by intercorrelations ranging from .70, p.e. .05 to .92, p.e. .01 (N = 50 university men). In comparing the intercorrelations in speeds of the five musculatures with the reliabilities for the separate musculatures, the differences are small enough that one could predict almost as well from one musculature to another as from one cycle to another for the same musculature. There would thus seem to be a general factor of speed of simple reaction as was found by Reymert, but further work would be necessary to demonstrate that this general factor would hold for different extents of movement, for stimuli in other sense fields or for other stimuli in the same sense field. For these extended relationships, moderate correlations have since been reported by Seashore, Buxton and McCollom (7).

3. 50 men slightly excelled 25 women (both groups laboratory students) in speed of simple reaction for each musculature. For the first cycle of fifty trials in each musculature, the differences were great enough to make the chances range from 947 to 994 in 1000 that differences in the same direction would be obtained in a repetition of the experiment, and these differences averaged even slightly more significant for the second fifty trials.

This portion of our findings therefore contradict those of Reymert, who considered that sex differences were small and tending to disappear with practice. We find that for our University of Oregon undergraduates the statistical differences are significant during the second cycle of fifty trials. It would be necessary to add more representative groups of cases to show that these sex differences held for people in general.

4. As found by Farnsworth, Seashore and Tinker (**2**), there is no correlation between speed of simple reaction and scores on a college aptitude or 'intelligence' test (American Council of Education test).

Further experiments by R. H. Seashore and others are to be reported in this journal showing the effects upon intercorrelations of simple reaction times of varying the following factors: (1) sensory modality (visual vs. auditory), (2) sensory attribute (visual color vs. visual space), (3) type of reaction (simple vs. discriminative), (4) nature of preparatory set (with or without warning signals) and (5) extent of movement (1 mm vs. 150 mm).

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GROUP FACTORS IN SIMPLE AND DISCRIMINATIVE REACTION TIMES *

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One of the earliest studies on interrelations of various kinds of reaction times is that of Reymert (**3**), who showed that the individual differences in simple reaction times of the principal musculatures to a sound stimulus were closely correlated, but that simple reaction times were not related to serial speeds (tapping). This result was confirmed by Seashore and Seashore (**5**) on a larger number of cases and with a longer and more reliable series of measurements in which they showed that for measurements on five musculatures having uncorrected reliabilities of $r = .87$ to $.90$ [1] the intercorrelations ranged from .70 to .93, centering around .84.

The work of Seashore, Buxton, and McCollom (**4**) on factorial analysis of fine motor skills of fifty college men showed that simple reactions to visual stimuli were correlated with those to auditory stimuli, $r = .55$. When the auditory and visual reactions were changed to a jump movement of six inches instead of merely pressing a key downward one millimeter, the correlation between the two jump tests was $r = .78$ and the remaining correlations between the four tests ranged from $r = .44$ to $.87$.

Perrin (**2**), studying fifty-one college students, reports a correlation of $r = .69$ between simple reaction to a color stimulus and discriminative reaction to color stimuli, indicating the presence of a group factor covering these two tests. Farmer and Chambers (**1**), studying very small numbers of young factory women, found that simple reaction to light, involving a short jump movement to the key correlated from $r = .20$ to $.83$ with discriminative jump movements to one of a number of keys. The simple pressing movement, however, correlated only $r = .17$ to $.47$ with the simple jump reaction time factors. The relationships obtained by Seashore, Buxton, and McCollom on a larger number of cases were slightly higher. As further

* From the laboratory of Northwestern University.

[1] Spearman-Brown corrected reliabilities, $r = .93$ to $.94$.

evidence of the limited range of these groupings, it may be noted that simple reactions did not correlate with speed of tapping or with serial discriminative reactions involving the same sense field (vision) and the same musculatures (right hand).

To summarize the previous work, it has been found that in simple-reaction tests (1) a change from one musculature to another makes relatively little difference in individual rankings, a point which has also been found for five or six other motor skills; (2) changes from one sense field to another, holding musculature and type of movement constant, produce a greater change in rankings, about the same as in making relatively slight changes in the type of movement. On account of a discrepancy between the results of Perrin and those of Farmer and Chambers, it has not been certain whether the group factor already discovered in reaction time extended also to the single discriminative reaction times.

The present study was therefore designed to test the relationship between discriminative single reaction times and also between prepared and unprepared single reaction times.

The apparatus included a Standard Electric Time Clock with six volt D. C. operated clutch, which was started silently[2] and simultaneously with the stimulus presentation by means of a pair of mercury switches. The stimulus was one of a pair of one-half watt General Electric A. C. neon bulbs (red light), placed two and a half inches apart, and the reactions were made on one of a pair of standard telegraph keys six inches apart. The apparatus was so wired that only the correct key for each light could break the circuit and stop the clock. The experimenter controlled the selection of the light which served as the stimulus by means of two preliminary switches. A record was kept of each individual reaction on a special data sheet.

Forty-seven male students at Northwestern University served as individual subjects for the study. Each was seated, facing the wall and with the box containing the lights and keys before him, in the opposite corner of the room to that in which the experimenter and the clock were located. Written instructions were read before each group of trials as to the exact procedure for that condition.

I. *Simple Prepared Reaction* consisted of pressing the right hand key, with the right hand and only the right hand light as a stimulus. The experimenter said 'ready' at an interval of one to three seconds before the stimulus presentation. In all tests the hand or hands were in position on the keys.

II. *Simple Non-Prepared Reaction* was similar to the first test except that the ready signal was not given, the light flashing at varying intervals.

III. *Discriminative Prepared Reaction.*—In this the subject responded to the right hand light by pressing the right hand key with the right hand, and to the left light by pressing the left key with the left hand. A ready signal was given as in the first test. A uniform order of presentation of right and left had been determined in advance by tossing a coin, and equalized between right and left hands by using opposite and inverted order during the second cycle.

IV. *Discriminative Non-Prepared Reaction.*—This was similar to the third test except that no ready signal was given.

Each subject was given twenty-five practice trials under each condition. Then Cycle One was given, consisting of fifty reactions to each condition. This was repeated in the same order for Cycle Two. Tests I to IV were given throughout in the same order as listed above. The average of the one hundred reaction times for the two cycles was used as the value for each test

[2] In the main experiments on 47 cases to be reported later, the clock was enclosed in a celotex sound reduction box, with a double window, in order to control the slight clutch sounds from the clock.

in computing the intercorrelations and the correlation between Cycle One and Cycle Two was the basis for calculation of reliability coefficients.

Since the intervals between successive stimulus presentations as a rule varied only from five to ten seconds, it cannot be said that the subject was completely unprepared. However, the degree of preparedness was somewhat lessened, as shown by the fact that the mean reaction times are slightly slower for each of the non-prepared conditions and that these results were rather consistent from subject to subject. Only four subjects showed an average faster for both non-prepared conditions than for the corresponding prepared tests. Evidence for the importance of work methods may be found in reports from a few subjects that they found it easier to set themselves when no ready signal was given.

In a preliminary investigation Kendall studied eighteen male subjects, using the same apparatus except that the discriminative response was made to red vs. blue neon type stimuli in the same location, rather than the spatial localization involved in the present study. Rather high rank-difference correlations were found, as shown by the figures in parentheses in Table I. Intercorrelations ranged

TABLE I

INTERCORRELATIONS AND RELIABILITIES ($\frac{1}{2}-\frac{1}{2}$) OF VISUAL SIMPLE AND DISCRIMINATIVE REACTION TIMES*

	Simple Prepared	Simple Non-Prepared	Discriminative Prepared	Discriminative Non-Prepared
Simple Prepared	.89±.02 (.86±.04)	.82±.03 (.76±.07)	.70±.05 (.41±.14)	.68±.05 (.66±.09)
Simple Non-Prepared		.87±.02 (.89±.04)	.78±.04 (.62±.10)	.78±.04 (.73±.08)
Discriminative Prepared			.83±.03 (.78±.07)	.93±.01 (.83±.05)
Discriminative Non-Prepared				.83±.03 (.89±.04)
Mean	19.7	20.3	26.2	27.2
Standard Deviation	2.33	2.30	2.86	3.10

* Upper figure in each cell represents values of r found by Helmick on 47 Northwestern University male subjects, using spatial discrimination. Lower values (of rho) in parentheses are those obtained by Kendall on 18 male subjects using color discrimination, apparatus otherwise the same.

from $r = .41$ to .83 with a central tendency around .67, and uncorrected reliabilities on the order of .85.

In the present experiment the uncorrected reliabilities obtained ranged from $r = .83$ to .89, averaging .85. The lowest correlation obtained was $r = .68$ between Simple Prepared and Discriminative Non-Prepared, the test in which both factors were changed. The highest correlations were obtained when the type of reaction was held constant and only the ready signal was changed. For Simple Prepared and Simple Non-Prepared the correlation was $r = .82$, and

for Discriminative Prepared and Discriminative Non-Prepared the correlation was $r = .93$. The median of the six intercorrelations was $r = .78$.

The results obtained by Kendall fall along a similar line, indicating that the same factor may be operative in both color and spatial discrimination. Although Kendall studied only eighteen subjects, the similarity of the correlations under the two types of discrimination lends consistency to the results.

In view of our correlations and the previously cited data of Seashore, Buxton, and McCollom, it would seem that the group factor in speeds of single reactions has been extended to include simple and discriminative reaction times for visual and auditory stimuli, with either short 'press' or longer 'jump' movements, and for both prepared and unprepared reaction times.

Whether this factor of speed in single reactions would extend to include such things as brake and steering reaction times in driving a car and operating other machinery under more distracting conditions is yet to be demonstrated.

The fact that simple reaction time is known to be uncorrelated with serial reaction, speed of tapping, and nearly all other motor skills so far measured should add sufficient caution against further extrapolation of our findings.

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